

**Project No.**

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# **GUIDE TO CONTRACTING ITS PROJECTS**

## **DRAFT FINAL REPORT**

Prepared for  
National Cooperative Highway Research Program  
Transportation Research Board  
National Research Council

TRANSPORTATION RESEARCH BOARD  
NAS-NRC  
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## EXECUTIVE SUMMARY

Through research and lessons learned from early [ITS] deployers, it has been concluded that the procurement of goods and services to support ITS deployments represents a major obstacle for transportation agencies responsible for deploying ITS. This obstacle can be attributed to the challenges associated with the procurement of goods and services to support the deployment of complex information technology (IT) systems. In response to this challenge, innovative procurement methods have been established.

In order to overcome the challenge of procuring ITS, transportation agencies must institutionalize innovative procurement methods. The first step towards this requires that transportation agencies become aware of innovative procurement methods and their appropriate usage. Concurrently, federal, state and local procurement policies, practices and procedures have to be considered and possibly tweaked to accommodate innovative procurement methods.

The use of inappropriate procurement methods may result in project cost-overruns, final designs that do not satisfy functional requirements and long-term maintenance failures. An appropriate method of procuring ITS must be flexible enough to accommodate the uncertainties of complex system acquisitions, while at the same time rigid enough to ensure that the responsibilities of the participants are fully defined and their interests protected.

In an effort to aid state and local transportation agencies with the identification of appropriate innovative procurement methods, the National Cooperative Highway Research Program (NCHRP) funded NCHRP Project 03-77 with the objective of developing a guide to ITS procurement.

A research team was established to develop the guide. The research team included veteran ITS and procurement practitioners with a wealth of experience in procuring complex IT systems. An NCHRP research panel was established to oversee the development of the guide. The project also involved the development of a website, a final report and complimentary outreach materials. The website automates the process prescribed in the guide.

As a result of this research it was determined that project, agency and environment characteristics and systems engineering and project management principles are key inputs into the process used to identify an appropriate procurement approach for a specified ITS project. A decision model (presented in Figure 1) was developed to represent this process. The Decision Model includes eight steps that must be performed to complete the process of defining the most appropriate procurement approach for an ITS project:

**Step 1 – Initial Decisions:** Step one will aid users in making fundamental procurement decisions that will ultimately affect the overall procurement strategy. These fundamental decisions consider the possibility of outsourcing and the procurement of consultant services. This step also directs users to skip to Step 7 of the Decision Model if either outsourcing or consultant services are used.

**Step 2 – Work Distribution:** Step two will help users determine whether the procurement should be performed as a single contract or multiple contracts.

**Step 3 – Define Project Category:** Step three will help users categorize your project with respect to complexity and risk. Understanding project complexity and risks is critical to determining an appropriate procurement package.

**Step 4 – Determine Agency Capability Level:** Step four will assist users in assessing transportation agency resources and capabilities as well as the environment in which the project will be procured.

**Step 5 – Select Applicable Systems Engineering Process & Candidate Procurement Package:** Step five uses the results of steps three and four to select applicable systems engineering processes and candidate procurement packages.

**Step 6 – Apply Differentiators:** Step six applies differentiators to the candidate procurement packages identified in step five. This step will help users reduce the number of procurement packages identified in step five.

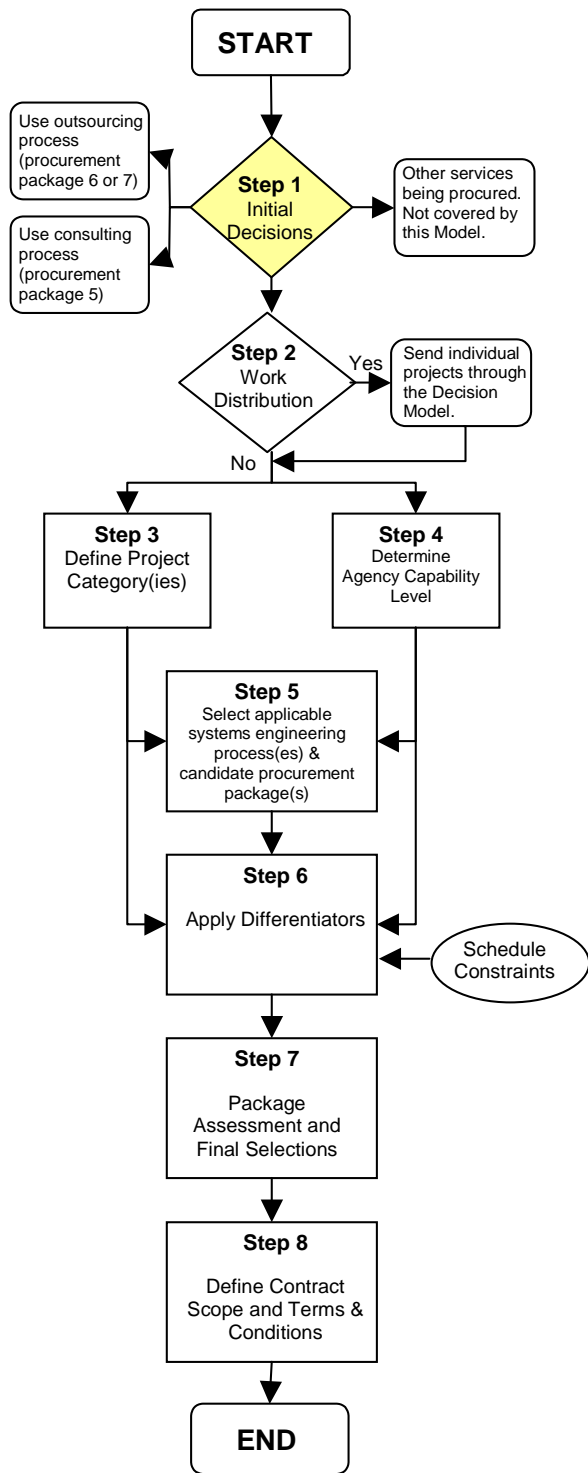
**Step 7 – Package Assessment and Final Selection:** This step suggests the involvement of agency procurement personnel to assist in making the final selection of the most appropriate procurement package.

**Step 8 – Define Contract Scope & Terms and Conditions:** The final step will assist users with the selection of the necessary terms and conditions to be included in the contract.

The guide further explains each step. Tables and worksheets are provided to aid guide users in executing the decision model.

The products of this research effort provide transportation professionals with tools to aid in the identification of appropriate innovative procurement strategies for a specific ITS project. In order to further advance the use of innovative procurement strategies to procure ITS, an aggressive outreach campaign is suggested that includes:

- Preparation and dissemination of brochures and other announcements intended to inform the profession of the availability of this research and the potential benefits of its use



- Preparation and delivery of training courses (either on-line or classroom) to instruct ITS professionals on the use of the guidelines
- Integration of the guidelines into existing curricula of the Federal Highway Administration's Professional Capacity Building Program including existing systems engineering and project management courses. Training should also be provided to FHWA field personnel regarding the availability of the guidelines and their application to the ITS procurement process.
- Inclusion of papers and presentations describing this work at national conferences sponsored by ITS America, the Institute of Transportation Engineers and NTOC.
- Offers of assistance through the FHWA Peer-to-Peer program, to agencies contemplating ITS procurements. This requires provision of prior training to Peer-to-Peer personnel in the use of the guidelines.

Suggested follow-up research activities include:

- Testing the decision model presented in the guide.
- Further consider the impact of organizational structure on ITS procurement.
- Integration of the results of this research into the systems engineering process.

# CHAPTER I

## INTRODUCTION AND RESEARCH APPROACH

### INTRODUCTION

Transportation professionals are placing increased emphasis on transportation system management and operations (TSMO<sup>1</sup> *tiz-mo*) enhancements versus capital improvements as solutions to transportation challenges. In some cases, TSMO enhancements are included within capital improvement projects. TSMO solutions often require the application of Intelligent Transportation Systems (ITS) technologies. ITS can be defined as information technology (IT) based systems, which along with their required communications infrastructure are used to improve the efficiency or safety of surface transportation. That being said, transportation professionals are now faced with the well-documented challenge of procuring IT.

Fortunately, transportation professionals do not have to tackle the challenge of procuring IT alone. Innovative procurement strategies have already been [and are currently being] developed that can help overcome this challenge. These procurement strategies utilize design-build and systems manager contracts and specified contract terms and conditions to ensure a successful IT procurement. In many cases, existing procurement policies, practices and procedures within the transportation organizations discourage the use of these strategies. Therefore, the two challenges faced by transportation professionals when considering the procurement of ITS are:

1. Identifying appropriate innovative procurement strategies.
2. Identifying and overcoming any restrictions imposed by existing procurement policies, practices and procedures.

Through NCHRP Project 03-77, a guide to ITS contracting has been developed to help transportation professionals mitigate these challenges. The guide presents a method for identifying appropriate ITS procurement strategies based on project and agency characteristics and constraints. Once transportation professionals have identified an appropriate procurement strategy, they are encouraged to consult agency procurement officials. At this stage, restrictions imposed by existing procurement policies, practices and procedures are identified and options for working within this environment can be formulated.

### RESEARCH OBJECTIVE

The objective of NCHRP Project 03-77 is to develop an ITS contracting guide that will provide a method for identifying appropriate ITS procurement strategies based on project and agency characteristics and constraints. This project also includes the production of an Executive Summary, brochures, and presentation materials that will promote the use of concepts presented in the guide. In addition, a website has been developed to automate the use of the procedures included in the guide.

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<sup>1</sup> TSMO concepts are further defined in [Getting More by Working Together – Opportunities for Linking Planning Operations](#).

## RESEARCH APPROACH

The following tasks outline the research approach.

### Tasks 1 and 2 – Literature Review and Survey of Contracting Methods

The objectives of tasks 1 and 2 are to:

1. Conduct a literature review of both transportation and non-transportation references.
2. Conduct a survey of local and state departments of transportation agencies in order to better understand the state of the practice [with respect to procuring ITS].

Much of the data collection for this effort came from an extensive review of existing literature from both the public and private sectors. Sources included:

Transportation Sources	Non-Transportation Sources
<ul style="list-style-type: none"> <li>o Transportation Research Board (TRIS Online)</li> <li>o JPO Electronic Document Library (EDL)</li> <li>o JPO Professional Capacity Building Materials</li> <li>o Institute of Transportation Engineers</li> <li>o ITS America Meeting Proceedings</li> <li>o State DOT Websites/Reading Rooms</li> <li>o FHWA/Turner-Fairbanks Highway Research Center</li> <li>o ITS Cooperative Deployment Network (ICDN)</li> <li>o AASHTO</li> </ul>	<ul style="list-style-type: none"> <li>o US Department of Defense</li> <li>o US General Accounting Office</li> <li>o US Department of Agriculture</li> <li>o US Department of Management and Budget</li> <li>o US Department of State</li> <li>o State and Federal Procurement Regulations (FAR, COMAR, etc.)</li> <li>o National Association of State Purchasing Officials</li> <li>o National Association of State Information Resource Executives</li> <li>o National Association of State Directors of Administration and General Services</li> <li>o Private [IT] Corporations (Unisys, IBM, etc.)</li> </ul>

As a result of this review, an extensive database of procurement references has been developed. The references presented in this database, as shown in Appendix A, served as the starting point for this research.

The information obtained from this extensive literature search was supplemented by a survey of state and local departments of transportation to obtain information about their current ITS procurement and contracting practices. The developed survey was web based. An email invitation to participate in the survey was distributed to select state transportations agencies including:

- Virginia Department of Transportation
- Texas Department of Transportation
- Kentucky Transportation Cabinet

- New York State Department of Transportation
- Illinois Department of Transportation
- California Department of Transportation
- North Carolina Department of Transportation

A survey instrument was developed by the research team and approved by the research panel. The survey solicited information on current practices and experiences with ITS contracting. The survey was followed-up by telephone to discuss the survey respondent's response to the survey.

The results of this task are summarized in Chapter II.

### **Task 3 – Categorize ITS Projects**

The objective of task 3 was to categorize ITS projects based on a number of factors including complexity of the project, the level of new development required, the scope and breadth of technologies involved, the amount of interfacing to other systems, the likelihood of technology evolution, and the fluidity of the requirements. Together, these factors influence the level of risk associated with an ITS project. Project risk may be defined in terms of schedule, quality, cost, or requirements risks. These risks can increase or decrease significantly based on the above factors and their associated characteristics. For an ITS project to be successful, it is important that the procurement process take into account the level of risk involved with a project. Thus, a thorough understanding of these factors, their associated characteristics, and their influence on the overall risk associated with ITS projects is very important.

Table 1 provided a starting point for identifying generic ITS project categories along with the factors and characteristics that support their definitions. The “starting point” included four ITS project categories ranging from “low” overall risk for a Category 1 project to “very high” overall risk for a Category 4 project. Table 1 also included a brief general description of a system implementation that might represent a particular ITS project category.

Therefore, task 3 validates Table 1 as an appropriate categorization of ITS projects. Even more important, an effort was made to validate the factors and their associated characteristics as they will ultimately be most useful in selecting the procurement components that can best address the overall risk associated with an ITS project.

Table 1. ITS Project Categories

	Category 1	Category 2	Category 3	Category 4
<b>Complexity</b>	Simple	Moderately complex	Complex	Extremely complex
<b>Level of New Development</b>	Little to no new software development / exclusively COTS based or based on existing proven software	Primarily COTS software or existing software based with some new software development or new functionality added to existing software - evolutionary development	New software development for new system, replacement system, or major system expansion including use of COTS software	Revolutionary development - entirely new software development including integration with COTS or existing legacy system software
<b>Scope &amp; Breadth of Technologies</b>	Application of proven, well known, and commercially available technology. Small scope in terms of technology implementation	Primarily application of proven, well known, and commercially available technology. May include non-traditional use of existing technology(ies). Moderate scope in terms of technology implementation	Application of new software along with some implementation of cutting edge software, hardware, or communication technology. Wide scope in terms of technologies to be implemented	New software development combined with new hardware configurations/components, use of cutting edge comm technology. Very broad scope of technologies to be implemented
<b>Interfaces to Other Systems</b>	No interfaces to external systems or system interfaces are well known (duplication of existing interfaces)	System interfaces are well known and based primarily on duplicating existing interfaces	System interfaces are largely well known but include interfaces to new existing systems/databases	System requires interfaces to both new and existing internal/external systems and plans for interfaces to "future" systems
<b>Technology Evolution</b>	Little to no impact on system in terms of technology evolution	Little to minor impact on system in terms of technology evolution. May involve only upgrades of COTS software	Technology evolution likely to have moderate to significant impact and must be adequately accounted for in system design	Technology evolution very likely with potential major implications on system to be implemented
<b>Requirements Fluidity</b>	System requirements are very well defined, understood, and unlikely to change over time. Formal requirements management a good idea, but not a necessity	System requirements are largely well defined and understood. Addition of new system functionality may require more attention to requirements management	New system functionality includes a mix of well defined, somewhat defined, and fuzzy requirements. System implementation requires adherence to formal requirements management processes	System requirements not well defined, understood, and very likely to change over time. Requires strict adherence to formal requirements management processes
<b>Overall Risk</b>	Low	Moderate	High	Very high
<b>General ITS Project Example</b>	Expansion of existing systems...adding additional field devices (CCTV, DMS, etc).	Implementation of computerized signal system.	Replacement of existing TMC software with the addition of new system functionality.	New TMC system implementation including field devices, interfaces to internal/external systems, etc.

The ITS project category validation was a subjective process that started with collecting a diverse cross section of real-world ITS project examples. Information was collected on over 200 ITS projects from the year 2000 to present, the sources of which were primarily AASHTO and US DOT operations and ITS web sites. Each project was given a cursory review within the context of the previously defined Categories in Table 1. The purpose of this initial cursory review was to (1) find a short list of examples that represented the previously defined Categories and (2) to determine if there were projects that didn't seem to fit within these Categories, hence requiring the addition of a category. A short list of 50 projects was developed that represented various types of the following systems.

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Emergency Management Systems
- Electronic Toll Collection Systems
- Electronic Fare Payment Systems
- Traveler Information Systems
- Weather Systems
- Rural Transit Mobility
- Rural Traffic Management
- Operations & Maintenance
- CVO/CVISN Systems

A matrix was then developed to ensure that there was a good distribution of projects across categories and system types, the rationale being that the ITS project categories, factors, and associated characteristics should, to the extent possible, be representative of many types of systems and not just, for example, freeway management systems. Next, at least four projects were selected that represent each ITS project category. Projects were also selected to represent the wide variety of system types. A total of 19 project examples were ultimately selected and an effort was made to describe each based on the factors and associated characteristics in Table 1. In this step, additional detailed information was sought for the ITS project examples through transportation agency or project specific web sites.

The results of this task, including an updated version of Table 1, are presented in Chapter II.

#### **Task 4 – Systems Engineering Process**

The proposed objectives of task 4 were to:

- Provide a description of both systems engineering and contracting concepts; and,
- Describe relationships and interactions between systems engineering and contracting concepts.

In conducting this task, it was determined that project management principles should also be described and related to both systems engineering and contracting concepts.

Relevant knowledge and experiences of the research team and the research panel as well as references obtained in Tasks 1 and 2 were used to derive the relationships between systems engineering, project management and contracting documented in Chapter II.

### **Task 5 – Recommend Contract Types**

The objective of Task 5 was to describe the process of planning and executing a system procurement. However, procurement planning cannot be performed in isolation, and for this reason, the Task 5 activities also consider the initial planning activities that must precede procurement planning (designated project planning in this report).

The procurement aspects of the planning process described led to the development of a decision model that will assist agencies in the selection of the procurement alternative best suited to their agency's capabilities and the characteristics of the system being considered for procurement. Real world ITS Projects were used to test the utility of the decision model.

The results of this task are presented in the Chapter II.

### **Task 6 – Prepare a detailed Outline of the Guide**

Based on the results of Tasks 1 through 5 a draft detailed outline of the “Guide to Contracting ITS” was developed. The research panel reviewed the outlined. Comments from the review panel were considered and a final version of the detailed outlined was generated.

### **Task 7 – Prepare the Guide**

Based on the results of Task 6, a draft “Guide to Contracting ITS” was developed. The research panel reviewed the guide. Comments from the review panel were considered and a final version of the guide was generated.

In addition to the guide, a CD was developed to automate the use of the guide.

### **Task 8 – Submit Report**

The concluding task was to prepare a research report documenting the entire effort for the NCHRP Project 03-77.

## CHAPTER II

### FINDINGS

#### **TASKS 1 AND 2 – LITERATURE REVIEW AND SURVEY OF CONTRACTING METHODS**

As indicated in Figure 1, the literature review yielded 117 references, and of those 117 references 39 were identified for further review. All of the references considered are presented in NCHRP format in Appendix A. A list of the references recommended for further review could be found in Appendix A.

There is an extensive bibliography of references describing both ITS and general IT procurements. As might be expected, many of these references address specific experiences without referencing the success or failure of their application. For this reason, they were not included in the list of recommended references. In addition, while there are many more non-transportation related references than transportation (ITS) related references, many were not included because they were not applicable to the ITS industry and the public-sector procurement constraints.

#### **Innovative Contracting Methods/Procurement Approaches**

Procurement components are combined to form a procurement approach based on project goals and objectives. Innovative procurement approaches are combinations of new or established procurement techniques that have been used to produce a novel procurement approach. The literature review produced both novel procurement components and procurement approaches.

#### *Pre-Qualification and Negotiation*

The literature review indicated that the pre-qualification of vendors is becoming increasingly popular among state and local government agencies, the fundamental premise being that the pre-qualification of vendors streamlines the procurement process. Government agencies can use the pre-qualification process to either short-list vendors for a particular procurement or to identify vendors to contract for “indefinite quantities”. Through pre-qualification, state and local government agencies are not burdened with reviewing the multitude of responses to solicitations for services and/or goods. Therefore, state and local government agencies can utilize more of their resources on negotiations with respect to the scope-of-work and other considerations. This streamlined process produces a positive effect on the project outcome. Procurement approaches that incorporate this streamlined process include:

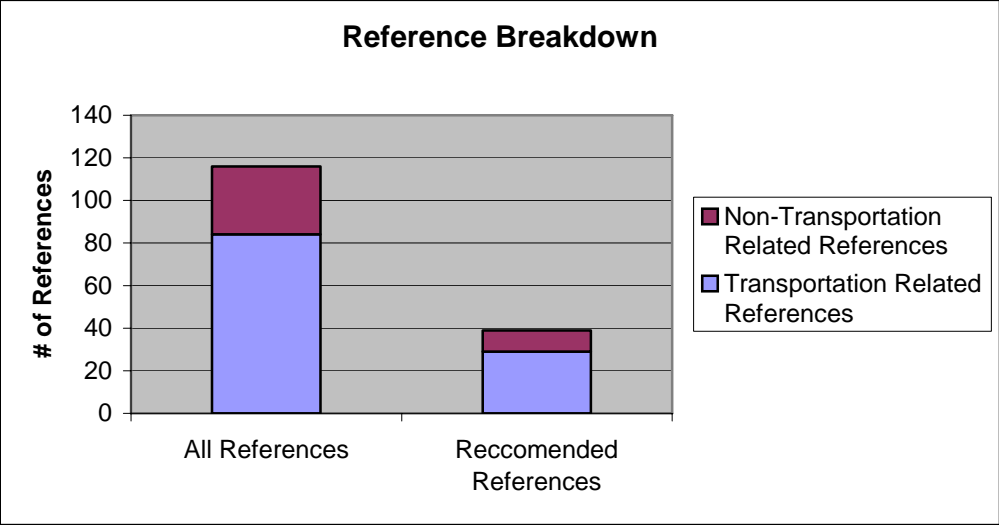


Figure 1. Summary of Literature Search Results

- Indefinite Quantities Contracts (IQC)/Indefinite Delivery Indefinite Quantities (IDIQ) Contracts
- The Information Technology Omnibus Procurement (ITOP) Program<sup>2</sup>
- Invitation to Negotiate (ITN)

### *Invitation to Negotiate (ITN)*

The ITN procurement process used throughout the State of Florida provides a novel approach for procuring ITS. An overview of the activities involved in the ITN procurement approach is outlined below:

- Step 1) FDOT develops and releases an ITN.
- Step 2) Interested vendors respond to the ITN.
- Step 3) Interested vendor responses are reviewed and either ranked or included in a next iteration of the ITN scope. The next iteration of the ITN scope will be only distributed to a “short-list” of best-qualified vendors based on the responses to the initial ITN.
- Step 4) Once the ITN scope has been finalized and re-distributed, then vendors are ranked according to their final responses.
- Step 5) The highest ranked vendor is selected for contract negotiations.

The ITN procurement approach has been chosen for several ITS deployments by the Florida Department of Transportation. FDOT utilizes the ITN procurement approach when they intend to procure technologies that are at their infancy stage of development. This is done in recognition of the fact that procurement of “cutting edge” technologies is hard to scope and therefore, introduces a lot of risks. The ITN procurement approach is intended to mitigate these risks. The effectiveness of this approach is still under evaluation.

### *Performance-Based Contracting*

Performance-based contracting is a good option for select ITS procurements. A performance-based contract specifies the final outcome of a task or project and leaves the method used to reach the final outcome up to the contractor/consultant. The task or project objectives are translated into measurable/quantifiable specifications. Successful completion of the task or project is gauged by these measurable/quantifiable specifications. The use of performance-based contracts produces the following benefits<sup>3</sup>:

- Enhances relationship between contractor and client
- Motivates the development and implementation of new ideas
- Innovative ideas, methods to keep quality high while reducing cost
- Direct relationship between performance and pay
- Creates greater ownership, commitment and accountability by the contractor
- Provides for greater management attention to the project

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<sup>2</sup> <http://www.eds-gov.com/itop2/>

<sup>3</sup> Based on project reference ID: 53, *Guideline to Managing Performance Based Operations and Maintenance Contracts*.

- Improves project execution, data collection and management
- Contractor assumes some associated risks

However, within the TSMO field, difficulties have been encountered with the definition of performance criteria (other than meeting schedules) that can be reliably quantified.

### *Design-Build*

The design-build work allocation method has long been identified as a tool for successful procurement of ITS. Several innovative permutations and variations of the design-build work allocation method have been established. For instance, the design-integration work allocation method is gaining popularity in other industries.

The Connecticut Department of Transportation (ConnDOT) utilized a unique variation of the design-build work allocation method to procure an advanced traffic data collection system. ConnDOT inserted a proof step in between the design and build steps. The proof step required the contractor to develop and test a prototype of the proposed system. Additionally, the contractor was required to conduct a system demonstration test. The proof step identified problems areas sooner, which made field-testing easier. The test also reduced the risk of incurring multiple change orders during the integration phase of the project.

### **Survey of Contracting Methods Employed by ITS Agencies**

This section presents the results obtained from a web-based survey directed to ITS agencies. The objective of this survey was to understand the current practice for contracting ITS projects across the agencies. The survey was aimed at ITS project managers and agency procurement officials.

#### *Survey Responses*

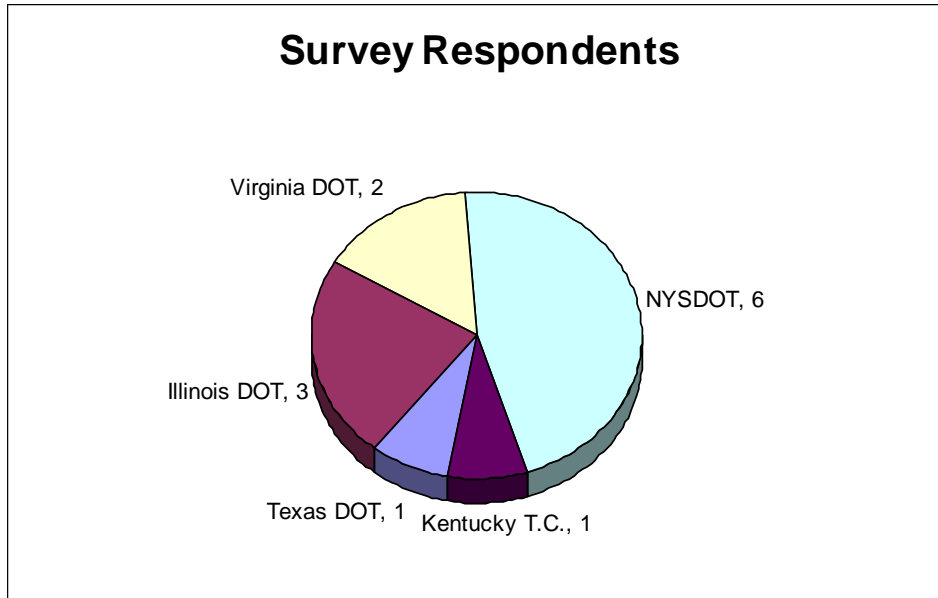
The following paragraphs present details on the agencies' practices for contracting ITS projects.

#### *Survey Respondents*

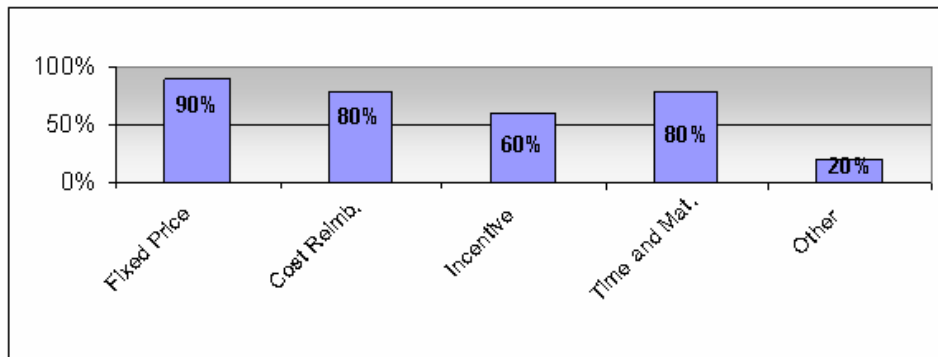
The total number of respondents was 13, which represented five agencies. These agencies are Kentucky Transportation Cabinet, Illinois Department of Transportation, New York State Department of Transportation, Texas Department of Transportation, and Virginia Department of Transportation (see Figure 2).

#### *ITS Organizational Information of Agencies*

Although, 62% of the respondents have recognized that their agency has an organizational unit specifically appointed for the acquisition and management of ITS systems, almost half of the respondents acknowledged that their agency uses outside assistance to manage/oversee ITS project acquisitions.



*Figure 2. Summary of survey respondents*



*Figure 3. Types of Contractor/Consultant Reimbursement Permitted.*

The survey also showed that 4 out of 5 agencies have the following in-house areas of expertise: IT System Administration, IT System Maintenance and IT System Operations.

### *Procurement Policies and Regulations*

Only 2 of the 5 agencies allow Design-Build contracting; these agencies are Virginia DOT and Kentucky TC.

Figure 3 shows the percentage of agencies surveyed that use different types of contractor/consultant reimbursement vehicles.

Moreover, the survey shows that 71% of the respondents reported that cost-reimbursable contracts require a ceiling; 57% of them stated that their agency does not restrict the maximum allowable overhead and does not have a limit on allowable fees (profits). 78% of the respondents reported that their organization uses indefinite quantity (task order) type of contracts.

All respondents acknowledged that their agency has a policy for intellectual property rights; one third of them reported that the agency has ownership or unrestricted license to use of all products developed under contract.

One hundred percent of the agencies reimburse consultants and contractors for project management cost. Likewise, all agencies permit sole source acquisition of proprietary software packages (MS Windows, Oracle, etc) as well as the acquisition of off-the-shelf application software (traffic management software, signal control software, dispatch software, etc). Only 30% of the respondents acknowledged that they have incorporated incentives in ITS contracts while 50% of them have incorporated penalties.

Finally, the survey shows that 56% of the respondents indicate that their agencies use IT industry certifications (such as the Capability Maturity Model (CMM) or ISO 9000) as a pre-qualification criteria during the procurement process.

### **TASK 3 – CATEGORIZING ITS PROJECTS AND ASSESSING AGENCY ITS CAPABILITIES**

Task 3 involved development of a method for categorizing ITS projects based on a number of key project factors and associated characteristics that can be used to identify a project in terms of its overall complexity and risk. For an ITS project to be successful, it is important that the procurement process take into account the level of risk. Equally critical to procurement is an agency's resources and capabilities along with the "environment" in which a project is planned, designed, deployed, and operated.

## Categorizing ITS Projects

Four categories of ITS Projects have been defined as follows:

- Category 1: Straightforward in terms of complexity and low overall risk
- Category 2: Moderately complex and moderate overall risk
- Category 3: Complex with high overall risk
- Category 4: Extremely complex with a very high overall risk

Project risk may be defined in terms of schedule, quality, cost, or requirements risks<sup>4</sup>. These risks can increase or decrease significantly based on the following factors and their associated characteristics:

- **Complexity.** The characteristics that describe this factor define the level of difficulty associated with implementing an ITS project in a particular category. The level of difficulty is directly related to subsequent factors and their associated characteristics.
- **Level of New Development.** The characteristics that describe this factor describe the use of commercial off the shelf (COTS) software and/or hardware compared with the level of new software development and/or hardware implementation associated with an ITS project implementation. The level of new development, particularly software development, typically has a significant impact on the overall risk associated with an ITS project.
- **Scope and Breadth of Technologies.** The characteristics that describe this factor include: (1) the level of technology implementation; and (2) the scope of technologies implemented by an ITS project. Levels of technology implementation range from the application of proven, well-known, and commercially available technology to the use of cutting edge technology. Scope refers to the range of technology implemented. For example, the scope associated with a Category 1 ITS project might involve installation of new field devices such as CCTV cameras that will be controlled by an existing traffic management center. On the other end of the spectrum, the scope associated with a Category 4 ITS project might involve, for example, construction of a new traffic management center building, installation of field devices (e.g., detectors, CCTV cameras, variable message signs, vehicle probe technology based on cellular geo-location), new central control system software with entirely new functionality, system of wire-line and wireless communications technologies, interfaces to transit, public safety, and commercial vehicle systems and databases. Another scope related characteristic involves the concept of phasing. Category 1 and 2 projects may be done as a single stand-alone project involving only one phase. Due to the complexity of Category 3 and 4 projects, they typically involve multiple phases, which is consistent with good practice (good practice being to break up large projects into small manageable pieces). Category 1 and 2 projects may actually be part of phases

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<sup>4</sup> *Intelligent Transportation System (ITS) Software Integration Project Risk Assessment and Mitigation*, 2002, Yermack, Larry, and Iserson, Andy, prepared for AASHTO.

under Category 3 and 4 projects. This is significant in that a Category 3 and 4 project may use a diverse mix of procurement components as opposed to a “one-size fits all” approach.

- **Interfaces to Other Systems.** The characteristics that describe this factor are based on the number of major subsystems as well as the number and complexity of existing and new system/database interfaces that will be included in an ITS project implementation. This ranges from no major subsystems and interfaces (or a duplication of well-known existing interfaces) for a Category 1 ITS project to a Category 4 ITS project that might include multiple major subsystems and multiple interfaces to new and existing systems both internal and external to the implementing agency as well as planning for future interfaces that don’t yet exist.
- **Technology Evolution.** The characteristics that describe this factor are based on an agency’s “perceived need” to account for the evolution of technology. The fact is that, with any category of ITS project, the probability of technology evolution is 100%. Technology installed today will “evolve” within a matter of weeks or months depending on what it is. Quite often, technology specified in procurement documents is outdated by the time it actually gets installed. Standards are often identified as a way to account for technology evolution; however, in some cases the rapid rate of technical progress leaves formal standardization efforts slow to catch up if the standards are formulated by relatively slow moving and deliberate standard-setting bodies<sup>5</sup>.

The idea of “perceived need” comes into play more for Category 1 and 2 projects. For example, an agency may consciously decide to implement CCTV camera hardware and control software that is compatible with their existing system. While this technology is evolving, an agency’s perceived need to take this into account may be influenced by having to wait for the emergence of CCTV standards and the associated vendor equipment that meets the standards. In this case, the agency will likely opt to deploy equipment based on their existing equipment and software. At some point in the future, as standards based CCTV equipment comes to market, the agency may decide to make changes to their central control system software so that they can deploy standards based hardware from different vendors in the future. When it comes to Category 3 and 4 projects, the need for taking technology evolution into account should be based less on perceived need and more on actual need. The reality is that the agency really doesn’t have a choice but to take technology evolution into account. For example, an ITS project that involves implementation of a mobile data communications system in conjunction with automatic vehicle location for service patrol vehicles will be impacted significantly by rapid changes in wireless communications technology. Technology evolution, in this case, is an actual need since not accounting for it can have a major impact on the long-term viability and ultimate success of the system.

In addition to the agencies perceived need to account for changing technology, it is helpful to think of technology evolution in terms of the expected usable life of a system, its subsystems, components, and underlying technology (both hardware and software).

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<sup>5</sup> Association for Information Systems (AIS)

Characteristics used to describe useful life under this factor include the terms “short”, “moderate”, “long”, and “extendable”. From a technology standpoint, short could be considered 3-5 years; moderate could be considered 5-7 years; and long could be considered 7-10+ years. The term “extendable” implies that a particular technology or component’s life may be extended at the end of its initial life. It is, however, difficult to apply the concept of expected useful life to an overall system. Therefore, these terms are used in Table 2 to describe three separate components of an ITS project: field devices, center-based hardware, and control system software, all of which can be expected to have different expected useful lives.

- **Requirements Fluidity.** The characteristics that describe this factor are based on how well requirements are understood and defined upfront along with the likelihood of requirements changes during the ITS project implementation. The characteristics also describe the level of requirements management that may be necessary based on the category.
- **Institutional Issues.** The characteristics that describe this factor are intended to describe an ITS project in terms of, for example, the need for new agreements (either intra or inter agency), modifications to existing business models, working relationships, or operational procedures, and a general need to work with non-traditional partners. Not addressing these issues in an ITS Project can lead to the failure of a technically successful implementation.
- **Overall Risk.** This is a brief description of the overall risk associated with a category and is based on all of the prior factors and their characteristics. The Overall Risk ranges from “low” for a Category 1 ITS Project to “very high” for a Category 4 ITS project.

Table 2 identifies four ITS project categories ranging from “low” overall risk for a Category 1 project to “very high” overall risk for a Category 4 project. Within each of the four categories, detailed characteristics are provided for each of the above factors.

The worksheet in Appendix C has been developed to assist with determining the ITS Project Category (complexity and risk).

Table 2. ITS Project Categories

	Category 1	Category 2	Category 3	Category 4
Complexity	Straightforward	Moderately Complex	Complex	Extremely Complex
Level of New Development	Little to no new software development / exclusively COTS software and hardware based or based on existing proven software and hardware.	Primarily COTS software / hardware or existing software / hardware based with some new software development or new functionality added to existing software - evolutionary development.	New software development for new system, replacement system, or major system expansion including use of COTS software. Implementation of new COTS hardware.	Revolutionary development - entirely new software development including integration with COTS or existing legacy system software. Implementation of new COTS hardware or even prototype hardware.
Scope & Breadth of Technologies	Application of proven, well-known, and commercially available technology. Small scope in terms of technology implementation (e.g., only CCTV or DMS system). Typically implemented under a single stand-alone project, which may or may not be part of a larger multi-phased implementation effort.	Primarily application of proven, well-known, and commercially available technology. May include non-traditional use of existing technology(ies). Moderate scope in terms of technology implementation (e.g., multiple technologies implemented, but typically no more than 2 or 3). May be single stand-alone project, or may be part of multi-phased implementation effort.	Application of new software / hardware along with some implementation of cutting edge software, hardware, or communication technology. Wide scope in terms of technologies to be implemented. Projects are implemented in multiple phases (which may be category 1 or 2 projects).	New software development combined with new hardware configurations/components, use of cutting edge hardware and/or communications technology. Very broad scope of technologies to be implemented. Projects are implemented in multiple phases (phases may be category 1 or 2 projects).
Interfaces to Other Systems	Single system or small expansion of existing system deployment. No interfaces to external systems or system interfaces are well known (duplication of existing interfaces).	System implementation includes one or two major subsystems. May involve significant expansion of existing system. System interfaces are well known and based primarily on duplicating existing interfaces.	System implementation includes three or more major subsystems. System interfaces are largely well know but includes one or more interfaces to new existing systems / databases.	System implementation includes three or more major subsystems. System requires two or more interfaces to new and/or existing internal/external systems and plans for interfaces to "future" systems.

	Category 1	Category 2	Category 3	Category 4
Technology Evolution	Need to account for technology evolution perceived as minor. Example would be to deploy hardware and software that is entirely compatible with an existing COTS-based system. Ramifications of not paying particular attention to standards considered minor. System implemented expected to have moderate to long useful life.	Need to account for technology evolution perceived as an issue to address. Example includes desire for interoperable hardware from multiple vendors. Ramifications of not paying particular attention to standards may be an issue, as an agency may get "locked-in" to a proprietary solution. Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have moderate to long life.	Need to account for technology evolution perceived as a significant issue. Examples might include implementation of software that can accommodate new hardware with minimal to no modification and interoperable hardware. Ramifications of not using standards based technology are considerable (costs for upgrades, new functions, etc.) Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have an extendable useful life.	Need to account for technology evolution perceived as major issue. Examples include software that can easily accommodate new functionality and/or changes in hardware and hardware that can be easily expanded (e.g. add peripherals), maintained, and are interoperable. Ramifications of not using standards based technology are considerable (costs for upgrades, new functions, etc.) Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have an extendable useful life.
Requirements Fluidity	System requirements are very well defined, understood, and unlikely to change over time. Formal requirements management a good idea, but not a necessity.	System requirements are largely well defined and understood. Addition of new system functionality may require more attention to requirements management.	New system functionality includes a mix of well defined, somewhat defined, and fuzzy requirements. System implementation requires adherence to formal requirements management processes.	System requirements not well defined, understood, and very likely to change over time. Requires strict adherence to formal requirements management processes.
Institutional Issues	Minimal- project implementation involves one agency and is typically internal to a particular department within the agency.	Minor- may involve coordination between two agencies. Formal agreements not necessarily required, but if so, agreements are already in place.	Significant- involves coordination among multiple agencies and/or multiple departments within an agency or amongst agencies. Formal agreements for implementing project may be required.	Major- involves coordination among multiple agencies, departments, and disciplines. Requires new formal agreements. May require new multi-agency project oversight organization.
Overall Risk	LOW	MODERATE	HIGH	VERY HIGH

## Assessing Agency ITS Capabilities

While an understanding of the above ITS project specific factors is critical to selecting the best procurement approach, there are a number of non-project related factors that will influence the optimal mix of procurement components (The next section on Task 4 discusses the following four procurement components: work allocation, method of award, contract form, and contract type). The following factors and associated characteristics pertain to an agency's (or organization's) capability to successfully manage an ITS project implementation (see Table 3). Agency capability factors include:

- **Personnel Experience.** It is critical that an agency, to the extent possible, have the necessary personnel with the appropriate experience and skills to oversee an ITS project implementation (ideally these are in-house personnel). Getting agency personnel actively involved in the design, development, implementation, operations, and maintenance is important to a successful ITS implementation, but this active involvement takes considerable amount of time and effort. These individuals might include (but is certainly not limited to) system administrators, maintainers, operators, software expertise, and even contracting and purchasing personnel that can help put together the best mix of procurement components together.

Agencies can also take advantage of expertise of Information Technology (IT) personnel either within or outside their departments. This expertise can take the form of technical expertise (e.g., hardware, software, communications) or even IT procurement expertise. While coordination with IT staff is advocated, relinquishing the authority for doing technology procurements (e.g., moving responsibility for procuring ITS related hardware, software, and communications from the DOT to another State department responsible for IT) is not necessarily recommended.

- **Organizational Experience.** An agency's experience with implementing ITS projects will have an impact on an ITS implementation. This doesn't imply that agencies who have implemented dozens of ITS projects do not experience any problems. However, they do have a feel for pitfalls to avoid and generally have had some time to put together a mix of in-house and consultant personnel that have the skills and experience to improve the success of an ITS implementation.
- **Organizational Structure.** Whether or not an agency is organized to support ITS projects can be critical to implementation success. While there may be aspects of an ITS implementation that are handled within an existing organizational structure, there may be a need to create new teams or offices devoted to, for example, ITS Operations, Development, Integration, etc. The more involved in ITS an agency gets, the more important it is for an agency to be organized to support developing and deployed systems, especially over the long-term.

*Table 3. Agency Capability Levels*

	Level 1	Level 2	Level 3
Personnel Experience	ITS assigned as part-time job to person with no staff and little to no specific ITS experience.	ITS assigned as full-time job with no staff or some part-time staff support. Person assigned has some specific ITS experience with Category 2 or 3 projects. Staff support (if it exists) has little to no ITS experience.	Full-time ITS Manager and staff with significant prior ITS experience. Staff support includes system administration, operations, and maintenance responsibilities.
Organizational Experience	Little to no experience with the possible exception of Category 1 ITS projects.	Experience with at least one Category 2 or greater project.	Experience with at least one Category 3 or greater project.
Organizational Structure	ITS responsibility not defined. Responsibility housed within organization with other mission or primary responsibility. Responsibility may also be scattered amongst organizational entities with no clear lines of responsibility.	ITS responsibility somewhat, but not adequately defined. Individual organizational units have ITS responsibility and have their own budgets, management and priorities; however, there are no definitive linkage between these units. An umbrella ITS organizational unit may exist, but may not have the budgetary authority to effectively manage sub-units.	Established organizational unit with budgetary authority and clear ITS responsibilities. Organizational unit ties all ITS responsibilities together and includes a procurement process that supports ITS acquisition (e.g., personnel, policies, and procedures).
Resources	Little to none. No identifiable ITS budget categories or identification of specific ITS funding within existing organizational units.	Some budget resources (e.g., ITS earmark funding) assigned to one or more existing organizational unit(s). Support for personnel, equipment, office space, and training expected to come from organizational unit(s) existing budget.	Identifiable budget category set aside for ITS. Budget includes support for all required personnel, support equipment, office space, training, and (if necessary), consulting support.
Management Support	Some mid-level management support for ITS/Operations, but little to no interest at top management levels. ITS/Operations not recognized as an agency priority.	Strong mid-level management support for ITS/Operations, with some interest/ involvement at top management levels.	Top level management support. ITS/Operations considered an agency priority within its overall mission.
Expectations	Not defined or limited to a lower category ITS project that's under consideration for deployment, expansion, or replacement.	Expectations exist for a few "special" ITS related projects. Expectations may or may not be realistic depending on if they've been managed properly.	ITS/Operations is part of both short and long range planning. Expectations are well defined with actual performance measures. ITS/Operations expectations focus on improvement and no on "status-quo."

- **Resources.** An agency needs many types of resources to achieve a successful ITS implementation. Personnel, funding, office space and equipment, and training represent just a few examples of these important resources. Obviously funding is important, but if funds are available, personnel resources are perhaps the most critical.
- **Management Support.** Upper management, including agency leadership, must buy-in to an ITS/operations philosophy in order for any ITS project to succeed. At the same time, intimate involvement in an ITS initiative by upper management may require changes in various aspects of a project implementation; hence the need for maintaining flexibility in procurement approaches.
- **Expectations.** This factor can make or break an ITS project. Managing expectations means not over promising, especially with regard to functionality or the time frame under which functionality will be deployed.

The worksheet in Appendix D has been developed to assist with determining Agency Capability Level.

#### **TASK 4 -THE RELATIONSHIPS BETWEEN THE SELECTED PROCUREMENT APPROACH AND THE SYSTEMS ENGINEERING PROCESS**

The application of systems engineering and project management principles to the acquisition of an intelligent transportation system will significantly increase the likelihood of a successful implementation. The contracting processes employed, to a large degree, determine the manner in which these principles are applied as well as the assignment of responsibilities for their application. In many respects the contracting processes used can have as much of an impact on the project's success as the statement-of-work and system specifications.

##### **Systems Engineering Basics**

A model has been developed by the systems engineering community that serves as the framework for defining a system life cycle. A system life cycle begins when the need for the system is conceived and ends when the system is discarded. The model includes a basic "V" shape along with wings to the left and right that are intended to represent a definition of the context within which the system is being developed, and the process for changes and upgrades respectively. The overall model is shown in Figure 4.

The left wing of the system lifecycle model represents the initial planning for the system. It defines the manner in which it fits into the technical and institutional context of the region, and is defined during the creation of the regional ITS Architecture. The key activities of this phase of the system life cycle are the identification of the regional stakeholders and establishing a consensus for the purpose of information sharing and long term operations and maintenance. Also included in the left wing of the model are the activities associated with establishing the feasibility of the project including a benefits analysis that defines the problem, the metrics by which the solution to the problem will be evaluated, establishes goals, and defines the benefit/cost analysis that will be used to justify the system and judge its success.

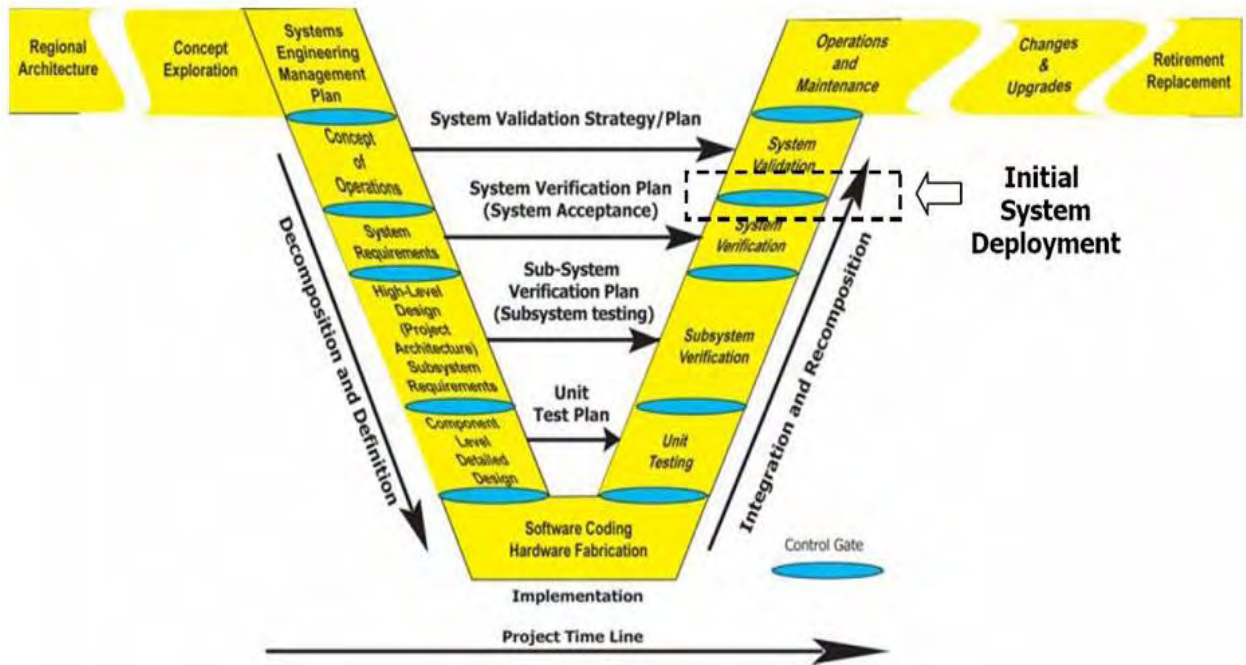


Figure 4. The “V” Lifecycle Model of Systems

The development of a specific system begins with the preparation of a systems engineering management plan and continues through the planning (represented by the concept of operations and shown on the left side of the “V”), through the system deployment and validation activities shown on the right side of the “V”. The arrows on the outside of the “V” in **Error! Reference source not found.** show the time sequence of these activities. In other words, the activities shown in the “V” also represent a progression in time when moving from the left side of the diagram to the right.

The systems engineering management plan includes a set of master plans and schedules that identifies the needed technical and project management information for the implementation of the project. These plans, along with the concept of operations become the control documents for the project implementation.

The “V” shape is used for the central part of the diagram to indicate the relationship between the planning, requirements and design activities on the left side of the “V”, and the testing and validation activities on the right side of the “V”. These relationships are indicated by the horizontal arrows in the diagram. Verification includes several sets of system testing beginning at the lowest level of unit testing, and proceeding to the highest level of verification identified as system verification testing (also known as acceptance testing). These tests are conducted to determine whether the “system was built right”. The validation process, which is also shown as a horizontal line in Figure 4, is used to determine whether the system satisfies the needs of the organization and its stakeholders as defined by the Concept of Operations. In other words, validation is used to determine whether the “right system was built”. As noted below,

validation can also be considered an element of the right wing of the system, since it is performed on an on-going basis once the system is operational. In other words, the system must be continuously evaluated to ensure that it is continuing to meet the evolving needs of the organization responsible for its operation.

In addition to validation, the right wing of the “V” includes the ongoing activities that occur following the acceptance of the completed system. These activities include operations and maintenance, the inevitable changes and upgrades associated with all high technology systems, and the ultimate retirement and/or replacement of the system. These activities are critically important, and must be subjected to the same systems engineering processes that were used during the system development. Plans must be developed for the system validation, as well as the operations and maintenance that define the metrics that will be used to determine the success or failure of these activities. Maintenance activities must include change control (including configuration management) contracting plans, and risk analysis. Contracting plans must be developed that define the resources that will be required to support these activities, and the staff and financial resources required for their successful execution.

Additional detail describing these steps can be found in Appendix G.

## **System Development Process Models**

Systems engineering process models define alternative applications of the “V” diagram to the systems engineering process. The process model also determines the procurement approach being used for the system acquisition. Alternative system development processes include:

- Waterfall Model
- Evolutionary Model
- Spiral Model

### *Waterfall Model*

As shown in Figure 4, the waterfall model defines a linear process in which the steps of planning, designing and implementing (and their further subdivisions) are performed sequentially. Because of its linear nature, the waterfall process is relatively inflexible, and as a result, its use should be restricted to the implementation of well-defined systems. In actuality, the steps shown in Figure 4 are no more than the representation of a single pass through the steps of the “V” diagram of **Error! Reference source not found.**

### *Spiral Model*

The spiral model is intended for the acquisition of systems involving the development of new applications that are not well defined. For example, this model might have been used during the development of control centers for the automated highway system. It is characterized by a repetitive process of planning, requirements, design and prototyping. Prototypes are then evaluated to determine the degree to which they satisfy the initial vision and concepts of operation as shown in Figure 5. It is an expensive model to implement, and for this reason its

use should be limited to situations in which new technology and processes that have never been implemented before are being developed.

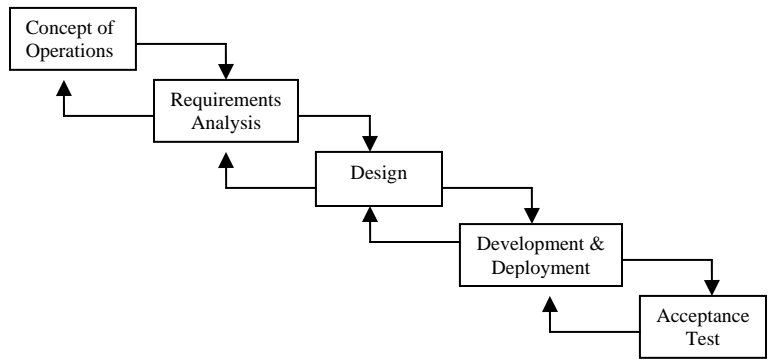


Figure 4. Waterfall Model of Systems Life Cycle

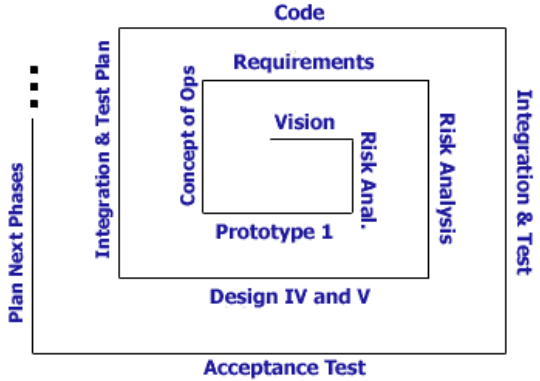


Figure 5. Spiral Model of Systems Life Cycle

## *Evolutionary Model*

The Evolutionary Model is a formalized description of a phased system development. As its name implies, the evolutionary model defines a sequence of stages such that the system evolves through a sequence of versions, such that each version is closer to its final vision.

The evolutionary model can be described graphically as a linear sequence of "Vs" connected end-to-end. Figure 6. It is recommended that the duration of these phases be from nine months to one year.

The evolutionary model has the benefits of "learning-by-doing", and for this reason, it minimizes the possibility of uncontrolled changes in requirements, and unanticipated cost or schedule overruns. It is applicable to most ITS system implementations

## **Cross-Cutting Systems Engineering Activities**

A number of activities are conducted continuously during the system acquisition process including configuration management, risk management, validation and verification, and metrics, serve as the supporting framework for the system development. High-level descriptions of these activities are provided in Appendix G of this report. Many systems engineering references and courses exist that define these activities in greater detail.<sup>6</sup>

## **Project Management Considerations**

It is also important to consider the general principles of project management that must be followed for a successful ITS project. In many respects, these principles are the basis for the steps that have been defined for the systems engineering process, and for this reason, they should be explicitly addressed when selecting the appropriate contracting activity. These principles have evolved from the recognition of the unique characteristics of software-based systems, which include the difficult (if not impossible) task of preparing definitive software specifications, the need to control changes in project scope (scope creep), and the challenging task of developing reliable cost and schedule estimates for the system development:

- **Collaboration** –A software-based project requires a close working relationship between the agency and the contractor to define the agency's needs and business processes, clarify uncertainties in the specifications, fully define all functions to be performed, modify the work as necessary to meet the needs of the users and stakeholders, etc.

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<sup>6</sup> Sage, A.P. and Armstrong, J.E., "Introduction to Systems Engineering," Wiley and Sons, 2000.

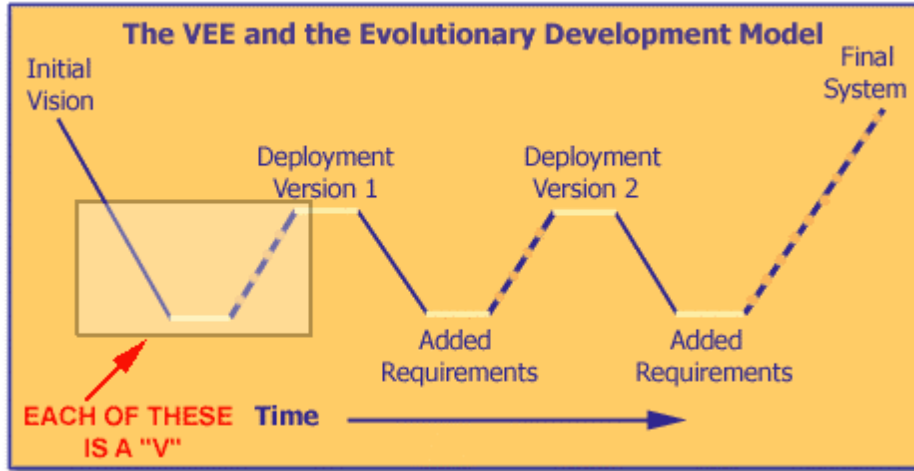


Figure 6. Evolutionary Model of Systems Life Cycle

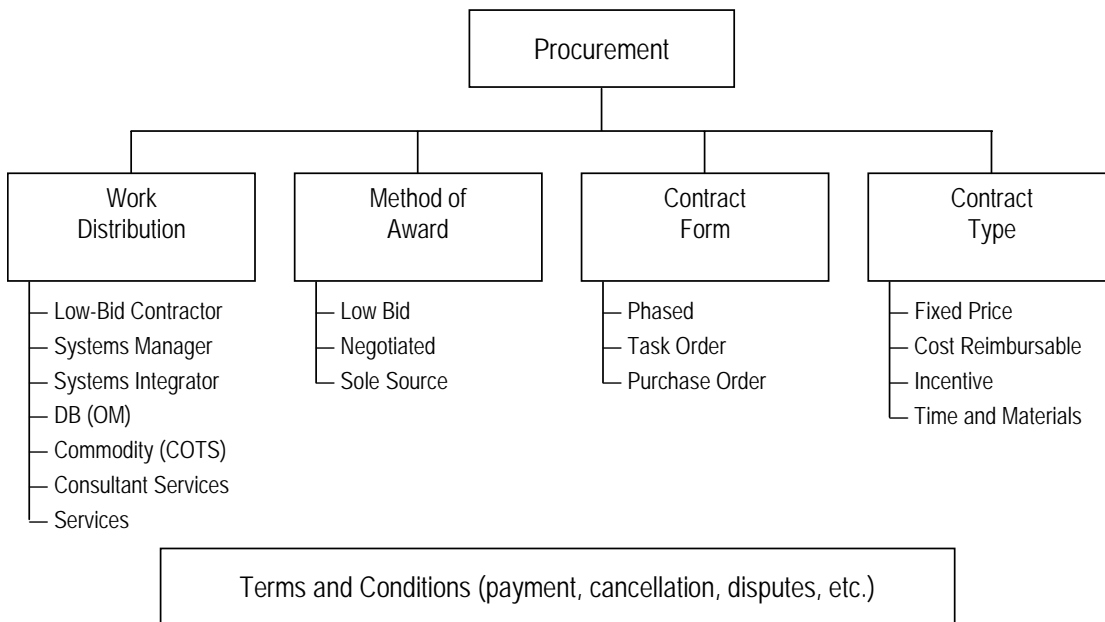


Figure 7. Contracting Framework

- **Off-the-shelf-solutions** – The use of commercial off-the-shelf (COTS) software offers a number of advantages over the development of unique software including the acquisition of a relatively mature (previously tested) package, the economic benefits of sharing the cost of upgrades with other agencies and the ability to acquire a package whose capabilities can be viewed prior to the initiation of system acquisition.
- **Prequalification/certification** – Many projects require offerors (bidders or proposers) to demonstrate that they are qualified to perform work on a planned project before their proposals (or bids) are evaluated. A recommended approach for prequalification is to require demonstration of knowledge and experience with the systems engineering process. This demonstration of systems engineering and development capabilities can be established by requiring the contractor’s verification that its processes have been verified by an accredited organization. The appropriate certification for software development is known as the Capability Maturity Model (CMM)<sup>7</sup>. CMM levels 2 or 3 are generally adequate for ITS projects.
- **Organizational Considerations** – The two elements of an ITS project with the greatest development risk, and the most uncertain costs and schedules are the software and systems integration activities. Whenever possible during an ITS procurement, organizational structures should be required that permit the agency and the software developer/systems integrator to collaborate on the work, and make necessary adjustments as the work progresses. This can be most readily accomplished if the systems integrator (who is likely to be the software provider) is the prime contractor.

These considerations should be kept in mind when reviewing the contracting alternatives described in the following section.

## Overview of Contracting

A framework has been developed to support the description and analysis of contracting alternatives analyzed during this research project. As indicated in Figure 7, contracting activities have been defined in terms of four dimensions plus the terms and conditions, which are, in effect, a fifth contracting dimension.

Definitions of the terminology used in this section are provided in the Glossary.

### *Work Allocation*

The work allocation category represents the project responsibilities defined by the agency for the contractor in the contract statement of work. These assignments are expressed in the systems engineering terminology – concept of operations, requirements, design, implementation and testing. They also include the crosscutting activities of configuration management, risk management, validation and verification, and metrics.

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<sup>7</sup> For more information see: [www.sei.cmu.edu/cmm/cmm.html](http://www.sei.cmu.edu/cmm/cmm.html)

**Low-Bid Contractor.** This form of work allocation involves the selection of a contractor for system installation using the low-bid process. The contractor bids on a system design, typically prepared by a consultant. The consultant's responsibilities are included in the "Services" category of work allocation. The qualified contractor submitting the lowest bid, compliant with the specifications is selected to perform the work.

**Systems Manager.** The systems manager form of work allocation utilizes an organization known as the systems manager that has been selected using the negotiated method of award. The scope of work defined by a systems manager contract may include all project activities associated with a system acquisition except for the provision of equipment<sup>8</sup>, electrical contracting and construction contracting. In other words, systems managers are operating under the constraints of consultant contracts, in that they can only participate in system implementation to the extent that personal services are being provided.

**Systems Integrator.** The role of the systems integrator is similar to that of the systems manager, except that the integrator is not involved in the planning and design stages.

**Design-Build (DB) Contracting.** DB contracting is based on an agreement "that provides for design and construction of improvements by a (single) contractor or private developer. Design-build contracts are typically preceded by the preparation of a partial design (sometimes designated a 30% design) prepared by a consultant. The design-build contractor is then responsible for completing the design as well as implementing the resulting system. This form of contracting is not allowed by some agencies.

**Commodity (COTS).** Contracting for the acquisition of commodities is applicable to ITS contracting to the extent that an agency is procuring commercial-off-the-shelf (COTS) products including both hardware and software. COTS procurements are quite different from consultant or low-bid contractor selections. The procurements are based on price and functionality of the COTS products.

**Consultant Services.** Work provided by consultants is limited to provision of personal services. Thus consultant services are a key element of a system acquisition when low-bid and design-build contractors are used for the system implementation. Consultant services are used not only for initial design, but also to supplement the development activities during the system implementation.

**Outsource Contractor.** Outsourcing is the process by which organizations (public or private) use external providers to manage or maintain certain aspects of their business. Outsourcing is increasingly used by the public sector in response to citizen's demands for expanded services and due to the difficulty of competing with the private sector for highly skilled personnel. Maintenance services are the most frequently used type of outsourcing in ITS. However, this form of contracting has also been used to provide system operations.

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<sup>8</sup> There are instances in which equipment can be furnished by the systems manager, subject to the interpretation of the agency's procurement organization. This is the case since the systems manager is only precluded from providing equipment and services that fall under the definition of construction (for projects using FHWA Federal-aid funds). As a result, many agencies permit the systems manager to furnish control center equipment such as operator workstations, large screen displays and communications routers.

**Services.** Contracts for other forms of services are frequently awarded during the life cycle of an ITS system. Technically, many of these other services may also be considered consulting services. The differentiation is made here to identify services that are outside the mainstream of system development. There are many forms of general services for which an agency may contract during an ITS life cycle.

### *Method of Award*

The method of award category of contracting defines the criteria used and steps taken to select a contractor to perform the work. The method of award is determined by the form of work allocation that has been selected. As indicated below, there are distinct differences between the various methods of award. These differences should be taken into account when selecting a form of work allocation.

**Low-Bid.** Low-bid contracting commonly referred to as sealed bidding is a contracting method that employs competitive bids, public openings of bids and low price awards.

**Negotiation.** Unlike formal advertising of a contract requirement which is precise, highly structured method of procurement with one definitive set of procedures, negotiation allows considerable flexibility, permitting the use of a number of different procedures in making awards. The negotiated selection is typically based on the evaluation of a technical approach, qualifications and experience as represented in a technical proposal and possible subsequent presentations to the agency.

**Best Value.** Best value selection is most often used for the selection of design-build contractors. The best value selection combines the features of the negotiated and low-bid procurements. During the first step in this process, offerors (contractors) submit their proposed designs for evaluation and negotiation with the procuring agency. Following these negotiations, and the development of an acceptable design, the contractor submits a bid for the design that has been approved. Selection may be made based on the proposal that offers the best value to the procuring agency.

**Sole Source.** Sole source procurement is the direct selection of a contractor without competition.

### *Contract Form*

The contract form defines the manner in which work is authorized. Three contract forms are defined, phased contracts, task order (or indefinite quantity) contracts, and purchase orders.

**Phased Contracts.** Phased contracts are the conventional form of contracting that is in use for the majority of projects including ITS acquisitions. Phased contracts divide the work into predefined activities. The contractor is authorized to begin work on a particular contract phase through the issuance of a simple letter by the agency.

**Task Order (Indefinite-Delivery) Contracts.** Indefinite-delivery contracts are used with contracts in which the required supplies and services are unknown at the time of contract execution. They provide a mechanism for the agency to place orders for these supplies and

services during the life or term of the contract. In the case of ITS projects, the supplies and services requested are defined in terms of task orders that define the work to be performed by the contractor. Indefinite delivery contracts are ideally suited to both the evolutionary and spiral development processes, since they permit the issuance of task orders for additional planning, design and implementation services as various evolutionary phases evolve.

**Purchase Orders.** A purchase order is a form of sole-source contracting used for relatively small procurements. The cap on purchase order contract size varies among agencies, but is typically less than \$50,000. Purchase orders are a simple, rapidly executed form of contract that usually contains a standard set of terms and conditions (payment, insurance, cancellation clauses, etc.) and a relatively brief description of the work to be performed.

### *Contract Type*

Contract types define the manner in which contractors are reimbursed for their services. This includes the payment of incentives (or penalties) resulting from the contractor's performance.

**Fixed Price Contracts.** Fixed Price contracts place the risk and full responsibility for all costs and profit or loss on the contractor. After award, price under this type contract does not increase regardless of the costs incurred by the contractor during the performance of the contract. This type contract places the burden on the contractor to maintain control of costs and perform in the most effective and efficient manner.

**Cost Reimbursement Contracts.** Cost reimbursement contracts provide for payment of contractor costs, to the extent identified in the contract scope of work or specification. Cost reimbursement contracts establish an estimate of the total cost for the purpose of obligating not-to-exceed funds for the contractor (except at its own risk) without the approval of the procuring entity. The contractor's risk is implicit in the fact that a fixed fee will be paid independent of the actual cost of performing the work. Thus, while the contractor is guaranteed a profit (as opposed to fixed price contracts where the contractor can lose money), the profit measured as a percent of total cost can vary considerably.

**Time and Materials Contracts.** Time and materials contracts allow for procuring supplies or services on the basis of direct labor hours at agreed to fully burden fixed hourly rates and materials at cost, including material handling fees as a part of material costs. Time and material contracts are generally used when it is difficult to accurately estimate the extent and duration of the work to be performed by the contractor. This type contract places the majority of risk on the procuring entity requiring extreme care to ensure the proper level of contract monitoring and oversight is obtained.

**Incentive Contracts.** Incentive contracts are designed to motivate contractor efforts that might not otherwise be emphasized and discourage contractor inefficiency and waste. When predetermined formula-type incentives on technical performance or delivery are included, increases in profit or fee are provided only for the achievement that surpasses the targets, and decreases are provided to the extent that such targets are not met. The incentive increases or decreases are applied to performance targets rather than minimum performance requirements.

**Performance-Based Contracting.** Performance based contracting is a form of contractor incentive or disincentive, in that payments made based on the outcomes resulting from the system installation. Contracting today and in the foreseeable future will place special emphasis on what the agency wants performed by the contractor, (outcomes), versus the manner in which the work should be performed. In other words, more general work scopes, and more specifics on final system performance defined in measurable terms.

The importance of selecting the proper type and method of contracting for ITS procurements cannot be over stated. The primary concern for using innovative contracting approaches is the reduction in time and resources from project planning through construction and final acceptance and completion.

### **Relationship Between Contracting and Systems Engineering**

The four components of the contracting framework are influenced by the work allocation, which in part, is determined by the systems engineering model, the system and agency characteristics. These relationships are summarized in Table 4.

These considerations, along with the definition of Contracting Packages for each Work Allocation alternative were developed during Task 5.

## **TASK 5 – DEFINING THE OVERALL PLANNING AND CONTRACTING PROCESS**

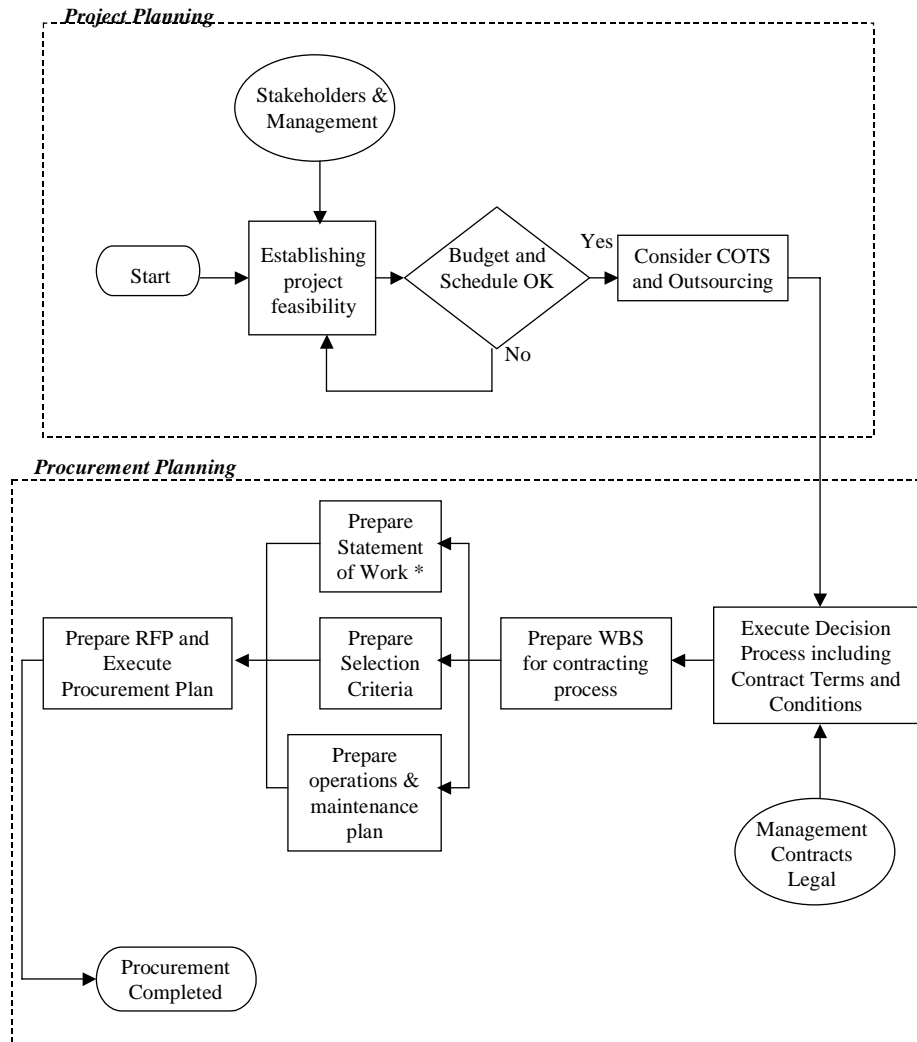
The objective of Task 5 is to describe the process of planning and executing a system procurement. However, procurement planning cannot be performed in isolation, and for this reason, the Task 5 activities also considered the initial planning activities that must precede procurement planning (designated project planning in this report). A decision model was also developed during Task 5 that serves as the basis for the guidelines produced as a separate product of this project. Additional details regarding the planning and procurement decision processes are provided in the guidelines and in Appendix J.

### **Project Planning**

Project planning is performed to ensure that the procuring agency and its stakeholders "have their act together" and that their plans are compatible with the financial and personnel resources of the agency. As shown in Figure 8, it is conducted prior to the initiation of a formal and expensive (at least to the contractor) procurement activity. It also addresses fundamental issues associated with the procurement regarding the use of COTS products and the possible use of outsourcing.

Table 4. Summary of Considerations in the Selection of Work Allocation

Work Allocation	Key Considerations		General Comments
	Systems Engineering	Project Management	
Consultant/Low-Bid Contractor	<ul style="list-style-type: none"> <li>• Only applicable to waterfall model</li> </ul>	<ul style="list-style-type: none"> <li>• Eliminates possibility of collaboration and risk management</li> </ul>	<ul style="list-style-type: none"> <li>• Use should be restricted to well-defined systems</li> </ul>
Systems Manager	<ul style="list-style-type: none"> <li>• Used with any systems engineering model.</li> <li>• Single contractor responsible for planning, design, implementation, and testing</li> </ul>	<ul style="list-style-type: none"> <li>• Permits use of collaboration and risk management</li> <li>• Increased flexibility for use of contract form</li> <li>• Permits qualification-based selection</li> </ul>	<ul style="list-style-type: none"> <li>• Additional contracting burden placed on agency</li> </ul>
Systems Integrator	<ul style="list-style-type: none"> <li>• Used with any systems engineering model.</li> </ul>	<ul style="list-style-type: none"> <li>• Permits use of collaboration and risk management</li> <li>• Increased flexibility for use of contract form</li> <li>• Permits qualification-based selection</li> </ul>	<ul style="list-style-type: none"> <li>• Additional contracting burden placed on agency</li> <li>• Requires additional consulting assistance</li> </ul>
Design-Build	<ul style="list-style-type: none"> <li>• Most applicable to the waterfall model.</li> <li>• Possible to include other models, but their application would be the responsibility of the contractor.</li> </ul>	<ul style="list-style-type: none"> <li>• Only moderate collaboration and risk management possible.</li> </ul>	<ul style="list-style-type: none"> <li>• Most applicable to systems with time constraints and requirement for continuity between the design and implementation</li> </ul>
Commodity (COTS)	For large systems, may be combined with one of the work allocation processes above (for example, the COTS product is acquired in the same manner as any other system component.)		
Outsource Contractor	<ul style="list-style-type: none"> <li>• Most applicable to the waterfall model.</li> </ul>	<ul style="list-style-type: none"> <li>• Only moderate levels of collaboration possible</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult to define and measure outcomes</li> </ul>
Services	N/A	N/A	N/A



\* May also include plans and specifications as required by the selected contracting alternative

Figure 8. The Planning Process

### *Establishing Project Feasibility*

The first step in the project planning process is establishing the feasibility of the project. This is not a trivial process. It involves establishing a team of stakeholders to develop an initial vision and to define initial project phases based on priority functionality. Constraints are also identified as well as a rough order of magnitude (ROM) cost, schedule, and resource estimates. Assuming project feasibility can be established in terms of its compatibility with available resources, project planning can be initiated. Project planning involves preparation of a project management plan and developing a procurement strategy consistent with an applicable system development process.

Establishing feasibility includes two steps; the development of a project scope, and determining whether the estimated cost and schedule for performing the work can be accommodated by the agency's available financial resources and time schedule requirements. If this process concludes that the project costs exceed the agency's budget capabilities, or the schedule is too long, it will be necessary to reduce the project scope. There is no other solution to this problem.

### *Other Considerations*

Once an acceptable project scope has been established, it is necessary to consider other fundamental approaches to the system development. Two of the most important considerations to be included in this step are the need for the development of a unique system vs. the purchase of a COTS solution, and the possible use of outsourcing. Both of these procurement approaches were discussed in the summary of Task 4 activities and in Appendices XX and YY. Decisions regarding COTS should be based on a critical comparison of needs with the features of available systems. If a good match can be achieved, COTS-type procurement should be considered. A project is a candidate for outsourcing if an agency concludes that it does not have either the personnel or experience to manage the system acquisition.

### **Procurement Planning**

Once the initial project planning has been completed, procurement planning can be initiated as shown in the lower half of Figure 8. Procurement planning identifies all the actions that must be considered for a successful ITS acquisition and contract award. The procurement plan will allow coordination and sequencing of actions throughout the contracting process. The complexity of a project can have a significant impact on the selection of a procurement strategy. ITS projects can range in complexity from those that are relatively straightforward as in adding field devices (e.g., CCTV, DMS, etc.) to an existing traffic management system, to those that are extremely complex such as the implementation of a completely new transportation management system. The procurement strategy for these two undertakings would be significantly different.

The procurement strategy must also take the agency's resources and capabilities into account. It must also consider the environment in which the project will be planned, designed, deployed, and operated. Addressing these issues is an important part of developing a procurement strategy.

Another important consideration is whether or not a project should be implemented using more than one contract. Not all contracts associated with a project require the same contracting approach. The magnitude of a project may involve a mix of complexity and incompatible services (e.g. construction, custom software development, systems integration, operations and maintenance) that diminishes the possibility for implementation success under a single contractor.

### *The Decision Model*

The following considerations set the stage for the Decision Model, which is based on the two dimensions of system engineering process and agency experience/environment.

- Systems engineering process has major influence on contracting approach.
- Defining the project complexity and agency characteristics, permit selection of the appropriate contracting approach.
- In actuality, there are four basic contracting processes (defined as packages here). The other contracting dimensions are adjustments to these processes.

**Contract terms and conditions are an important element of the contracting process. They are defined once a package has been selected.**

**The Basic Model (Structure and Packages):** The four dimensions of procurement described earlier provide a structured representation of the contracting process (procurement). The purpose of the selection is to identify the combination of items (one from each of the four dimensions) that are most appropriate for the project characteristics and the agency's capabilities.

Early in the development of this process, it was recognized that there are only a few unique combinations of these items (designated work packages). These packages are the fundamental output of the selection process. Contract terms and conditions are selected as a separate step. The package numbers shown in Table 5 are referenced in the initial steps of the decision process. Generally, packages 1 through 4 are used for traditional system implementation, although they can obviously be used for other purposes. Package 5 is either a supporting function for the system implementation, or may be used for numerous other consultant activities. Packages 6 and 7 are used for the provision of activities (an internal agency process such as inspection, maintenance, operations, mowing, or signal timing) and functions (an entire agency service such as traffic management, traveler information or toll collection) in a manner that reduces the agencies staffing requirements. Packages have not been defined for the "other" category of the work allocation dimension.

Table 5. Procurement Packages

Package No.	Work Allocation (Package Name)	Method of Award	Contract Form	Contract Type	Comments
1	Commodity Supplier	Low-bid selection of prequalified packages	Single phase or purchase order	Fixed Price	Used for COTS procurements
2	Low-Bid Contractor with Consultant Design	Low-bid for contractor	Phased or Task Order	Fixed Price for contractor incentives optional	Consultant performs 100% of design. May provide additional services during implementation
3	Systems Manager	Quality-based selection (negotiated procurement)	Phased or Task Order	Fixed price, cost plus or time & materials incentives optional	Field equipment procured by agency using low-bid process
4	Design-Build Contractor with Design Consultant	Best-value selection (based on consideration of price and quality)	Phased	Usually fixed price, cost plus or time & materials incentives optional	Consultant provides 30% design.
5	Consultant	Negotiated	Phased or Task Order	Fixed price, cost plus or time & materials incentives optional	Used for system design and many other consultant services
6	Outsourcing Agency Activity	Low-bid may be based on rates	Usually single phase	Fixed price or time & materials incentives optional	Typical activities include maintenance, operations, signal timing, etc.)
7	Outsourcing Agency Function	Best value or low-bid	Single phase	Fixed price, cost plus or time & material contracts Incentives optional	Typical functions include traveler information and toll collection. May be public-private partnership

The following process is presented as a sequence of steps that must be followed to arrive at the selection of a work package, followed by the identification of appropriate terms and conditions. The steps of the selection process are described in detail in the Guidelines and in Appendix J.

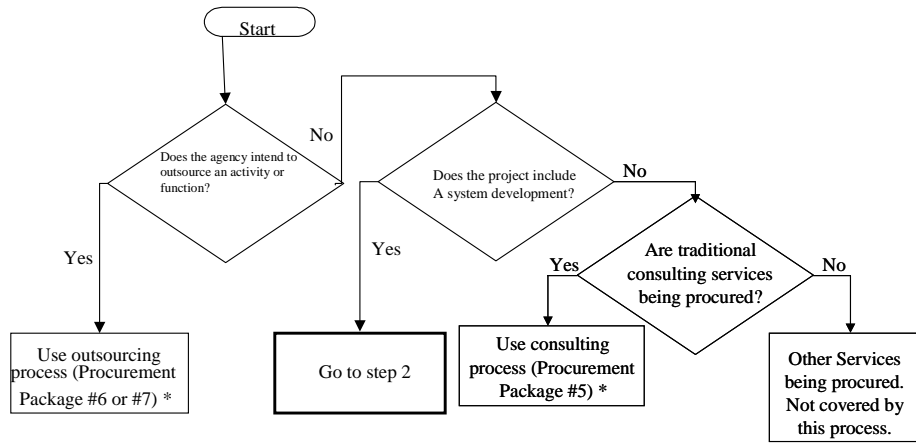
*Step 1* - The first step in the decision process is to identify the fundamental project characteristics that differentiate between a system development, a consultant contract and an outsourcing contract. These differences were determined during the project planning activities described earlier. This logic is formalized in Figure 9, which leads directly to the identification of an appropriate procurement package or guides the user to the more complex steps required for system development. If a procurement package is directly selected, the user can proceed directly to Step 7 (consultation with procurement officials). The process that should be followed for the execution of the remainder of the decision process is shown in Figure 10.

*Step 2* - The second step (Step 2) in the process determines whether the acquisition should be performed as a single project or multiple projects. It is shown as one of the initial activities the decision model, since the model must individually consider each of the individual projects resulting from this decision. In other words, it is not necessary that each project be executed using the same contracting process. This is particularly true when the nature of the work in each contract is different. For example, one project may include the central system (including software) implementation, while another project might consist only of field installations.

*Step 3* - The third step of the process (Step 3) is the definition of project categories. This step relies on the work performed during Task 3 of this NCHRP project (see Table 2) that identified categories of project difficulty using the characteristics of the work to be performed. During Step 3, Table AA is used to determine whether the project is a Category 1, 2, 3 or 4 project.

*Step 4* - The fourth step involves a determination of the agency's capability level. This step uses the information in Table 3 to determine the level that best suits the agency managing the system acquisition. In essence, this step is used to assess the agency's organization, experiences and resources relative to ITS procurements.

*Step 5* - Step 5 is one of the key steps of the process in that it is used to identify the appropriate contracting and systems engineering processes for the project being initiated. To execute this step, it is important to understand the alternative systems engineering processes described in Task 4. The alternative processes (also known as models) include the Waterfall Model, the Evolutionary Model, and the Spiral Model.



*\* Following the identification of a procurement package, go directly to step 7 of the decision process.*

Figure 9. Initial Decisions – Step 1

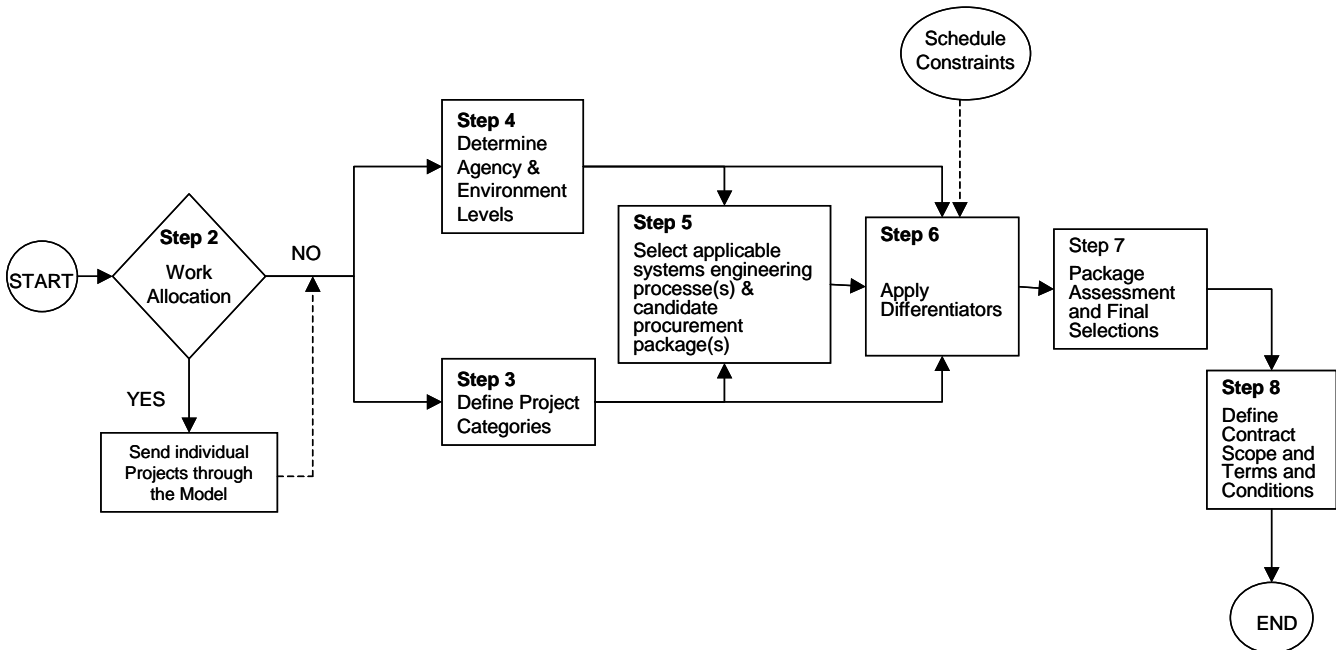


Figure 10. The Decision Model – Steps 2 through 8

The decision matrix shown in Table 6 is used as the basis for this step. To use this matrix, it is necessary for the agency to have identified its project category, and its organizational level of capability. The agency then identifies the columns and rows of the matrix that match this combination of capabilities and levels. The intersection of the applicable column and row identifies the cell that defines the procurement package or packages that should be used.

The COTS entries reflect the fact that a simple system, based entirely on a COTS product should be acquired using the commodity procurement package. When COTS products are part of a larger system, other procurement packages may be used (i.e. the product may be part of a proposal for low-bid, systems manager, or design-build procurements). A design-build contractor or a systems manager may decide to acquire a COTS product during the system implementation. If this is the case, the product should be acquired by the contractor using a commodity procurement package.

Step 6 is provided to assist in the selection of a specific approach, when multiple packages are recommended.

*Step 6* - The next step in the process, Step 6, is to be used when more than one procurement package type is identified as acceptable during Step 5. It provides some additional criteria to help reduce the number of alternatives. These criteria are listed below:

- Systems manager is preferred to design-build when significant amount of new software development required.
- Design-build is preferred over systems manager only for major projects when significant amounts of field construction are involved and there is a desire to reduce implementation delays associated with having to administer multiple procurement contracts.
- The evolutionary systems engineering model is preferred over the spiral model because it is less costly and easier to apply. The spiral model should only be used in the event that complex new developments are required.
- If a project includes both new software and field construction, consider splitting it into multiple contracts.
- Low-bid contracting should only be used if required by agency policy, and/or projects are limited to field construction and supply of off-the-shelf equipment.
- Commodity procurement is only applicable if an existing package is available that does not require any modification to meet agency's requirements except for:
  - o New drivers for interface with communications and field equipment,
  - o New database reflecting system configuration, and
  - o New map graphics.

Table 6. The Decision Matrix – Step 5

Project Category	Organizational Level		
	Level 1	Level 2	Level 3
1 – Low	<ul style="list-style-type: none"> <li>• Waterfall</li> <li>• SM or DB*</li> </ul>	<ul style="list-style-type: none"> <li>• Waterfall</li> <li>• Low Bid*, Commodity, SM or DB</li> </ul>	<ul style="list-style-type: none"> <li>• Waterfall</li> <li>• Low Bid, Commodity, SM or DB</li> </ul>
2 – Moderately Complex	<ul style="list-style-type: none"> <li>• Evolutionary</li> <li>• SM or DB*</li> </ul>	<ul style="list-style-type: none"> <li>• Waterfall or evolutionary</li> <li>• Low Bid*, SM or DB</li> </ul>	<ul style="list-style-type: none"> <li>• Waterfall or evolutionary</li> <li>• Low Bid, SM or DB</li> </ul>
3 – Complex	Not recommended	<ul style="list-style-type: none"> <li>• Evolutionary</li> <li>• SM or DB</li> </ul>	<ul style="list-style-type: none"> <li>• Evolutionary or spiral</li> <li>• SM or DB</li> </ul>
4 – Extremely Complex	Not recommended	<ul style="list-style-type: none"> <li>• Evolutionary or spiral</li> <li>• SM or DB</li> </ul>	<ul style="list-style-type: none"> <li>• Evolutionary or spiral</li> <li>• SM or DB</li> </ul>

*Notes:*

First line is the systems engineering technique, second line is the procurement package

DB = Design Build

SM = Systems Manager

\* - Consulting services should be used while project is underway

If after considering these differentiators, multiple solutions still remain, the preferred alternative should be chosen based on the preferences of the agency's procurement officials (See Step 7).

*Step 7* - Step 7 is a critical step for all procurements. If it has not been done already, at this point it is imperative to discuss decisions made to this point with agency procurement personnel. It may also be desirable to include legal personnel to discuss intellectual property rights, which must be considered during the preparation of terms and conditions in Step 7. Procurement officials must also participate in the selection between multiple options.

*Step 8* - The final step in the decision process is the selection of the necessary terms and conditions to be included in the contract. Some terms and conditions are required for all types of contracts. Others are only suitable for certain types of contracts (i.e., commodity supplier, low bid with design consultant, system manager, and design-build contractor).

### **Procurement Planning**

Following the selection of a contracting approach along with its associated terms and conditions, it is possible to continue the contract planning activities including the identification of the activities to be performed, preparation of a schedule, and a contract statement of work. In addition, the contracting process must be defined including prequalification requirements, evaluation criteria, and the members of the contractor selection panel. The contract statement of work (SOW) must include all of the significant systems engineering activities required for a successful project execution as well as reporting requirements, deliverables, schedules, and the responsibilities of both the contractor and the agency. If a task order contract is anticipated, the statement of work must also define the mechanics of the task order process. Perhaps most important, the SOW should define requirements for ongoing support as well as the anticipated requirement for maintenance services to be provided by the contractor following system acceptance. Procurement planning should also take into account the agency resources required during the system acquisition including both personnel and facilities.

### **Decision Model Testing**

The five projects shown in Table 7 were selected to test the procurement model. The table shows the procurement strategies that the decision model recommended for each project. The testing concluded that the recommendations of the decision model are appropriate and are comparable to the ones previously used for the projects. Since these projects are all, generally considered to have been successful, the model is considered to have passed these preliminary tests.

Table 7. Decision Model Test Results

ITS Project Description	System Type	Project Cat.	Org. Level	Model Recommendation		Procurement Strategy Used
				System Development Process	Procurement Packages	
TRANSMIT: Install additional transp. readers on Belt Parkway, Van Wyk, Cross Island, etc	FMS Software Development	1	2	Waterfall	SM for software development	Work Allocation: DB / Method of Award: Negotiated / Contract Form: Phased / Contract Type: Fixed Price
	FMS Field Installation	1	2	Waterfall	DB for field installation	
Expand FMS/EOC in Baton Rouge, LA	FMS	2	1	Evolutionary	DB preferred over SM because significant amount of field construction is required. Can use Design Consultant and DB Contractor	Work Allocation: SM / Method of Award: Negotiated / Contract Form: Phased / Contract Type: Fixed Price
Maintain ITS Equipment in Virginia I-81 Corridor	O&M	2	1	N/A	Other Services being procured. Skips steps 1-4 from decision model. Outsourcing an agency activity: Low-bid selection may be based on rates. Fixed price or time & material contracts. Can use incentives such as performance-based contracting	Work Allocation: Services / Method of Award: Negotiated / Contract Form: Task Order / Contract Type : Incentive
Integrate operations of fixed-route and demand-response paratransit systems in Brownsville, TX	TMS	3	2	Evolutionary	Low Bid. Requires design consultant & low bid contractor	Work Allocation: SM / Method of Award: Negotiated / Contract Form: Phased / Contract Type : Fixed Price
Capital Wireless Integrated Network (CapWin) Project	PS	4	3	Evolutionary or Spiral	SM for software development; Low bid contractor for field construction and field equipment supply	Work Allocation: SM / Method of Award: Negotiated / Contract Form: Task Order / Contract Type : Fixed Price and T&M

FMS = Freeway Management System  
TMS = Transit Management System  
ETC = Electronic Toll Collection  
PS = Public Safety  
O&M = Operations & Maintenance

SM = System Manager  
DB = Design Build  
T&M = Time and Materials

## CHAPTER III

### INTERPRETATION, APPRAISAL AND APPLICATIONS

This section summarizes and interprets the findings of the research relative to the procurement and subsequent acquisition of intelligent transportation systems. Since the primary objective of the study was the development of procurement guidelines, this information focuses on the background and techniques associated with the development of a process that can be used by agencies for the selection of the best procurement approach.

**Innovation in procurement primarily exists in the areas of incentive-based contracting.** Contracting processes are constrained by state policies and procedures. This leaves very little latitude for experimenting with new contracting approaches. In spite of this constraint, some agencies are considering various types of incentive-based contracting in which payment terms are directly linked to contractor performance. Traditionally, incentive-based contracting has focused on delivery of products ahead of schedule. New techniques are being explored in which incentives are based on the impact of the new system on traffic flow or other measures that reflect the effectiveness of the new system. Care must be taken when defining these measures to ensure that they are achievable and measurable, in a dynamic environment with changing traffic demand. Because of the unproven nature of incentive-based contracting for ITS, as well as its potential complexities, it was described but not recommended as an alternative for the contracting process.

**Design-build contracting is receiving widespread acceptance for construction projects, but must be applied cautiously to ITS projects.** Design-build contracting is becoming a popular method for reducing the time required for highway construction and other civil sector projects. It involves the preparation of a 30% design that is used as the basis for the best-value selection of a design-build contractor. Its applicability to ITS is limited to large projects that typically include significant field construction. However, the requirement for an initial 30% design precludes the design-build contractor from participating in the initial planning and requirements definition stages of the project. For these reasons, design-build contracting was recommended for projects involving field construction. Projects requiring complex software development for which design-build contracting is being considered, should either be divided into multiple contracts, or an alternative form of contracting should be used.

**The type of procurement selected for ITS projects is dependent both on the nature of the project as well as the organization and experience levels of the procuring agency.** The survey of existing practices concluded that agencies tend to use a single contracting approach for all ITS projects based on past experience as well as existing agency policies. However, a review of sample projects demonstrated the importance of considering both the agency's experience as well as the complexity of the project prior to the selection of a procurement approach. Differing procurement approaches provide varying degrees of contractor support and permit the use of differing systems development methodologies. A matrix was developed that described the important agency capabilities. This matrix along with a companion

matrix that defined alternative system characteristics are used for the selection of procurement and systems engineering approaches to be used for the project procurement and implementation.

**The risks associated with an ITS procurement are reduced if stovepiping is eliminated.** (Stovepiping is an approach in which responsibility for planning, design, implementation and operation resides in separate organizational units.) The successful implementation of a system requires a fully integrated team (including the contractor) that can work together in a collaborative fashion to ensure that requirements reflect the agency's business process. An integrated team will also ensure that the system design reflects the requirements, and that the implementation reflects the design. It is difficult (if not impossible) to accurately define requirements and specifications for a system without continuing interaction among the stakeholders (users) of the system, its planners, designers and implementers. For this reason, the guidelines give preferential treatment to contracting approaches that provide for collaborative interaction among members of the system development team. Research conducted on this project did not directly consider the number of agencies in which stovepiping occurs, nor did it attempt to quantify the impacts of this type of organization. Additional research in this area has been recommended.

**The systems engineering model (waterfall, evolutionary, spiral) used for the system implementation influences the type of procurement used.** A review of systems engineering technology identified three fundamental types of system development, each of which is appropriate for specific types of projects. The waterfall approach is most appropriate for acquisitions of well-defined mature technology. The evolutionary approach is appropriate for large scale system procurements involving new software development. The spiral method is appropriate when new technological capabilities are being implemented. Not all systems engineering methodologies can be implemented using the same procurement approaches. This is reflected in the procurement guidelines, which combine the recommended procurement approach to the systems engineering methodology that should be used.

**ITS procurement can be divided into seven basic types (denoted packages in the guidelines) which embody the contractor's responsibilities, selection process, payment terms, and contract form.** Analysis of the procurement process led to the development of a four dimensional model that included work distribution (who does what), method of award (how contractors are selected), contract form (phased, task order, etc.), and payment terms (fixed price, cost reimbursable, incentive, time and materials). At first, it appeared that there were an infeasible number of possible combinations of these four dimensions. However, upon further analysis, it was found that many of these combinations are incompatible with each other. As a result, seven fundamental types of procurement packages were defined which serve as the fundamental output of the selection procedures contained in the guidelines.

**When considering procurement alternatives it is important to consider the possibility of using commercial-off-the-shelf (COTS) products for ITS implementation.** The review of existing practices concluded that few agencies emphasize the procurement of off COTS products when acquiring a new system. There were some exceptions, such as the procurement of a traffic management system by the Utah Department of Transportation. However, even in this case, significant work was required to adapt the system to the agency's

requirements. This is somewhat at odds with practices of agencies outside of the transportation community, in which COTS procurements are being increasingly emphasized, due to the higher levels of maturity and lower cost associated with these systems. For this reason, the acquisition of COTS products through a commodity type procurement process has been included as an alternative in the procurement selection process.

**Some states are using outsourcing as an alternative to conventional procurement practices for acquisition of new systems or capabilities.** The research concluded that outsourcing is a useful approach for the acquisition of new systems when the agency requires a new capability but does not have the personnel resources to manage its implementation, operations and maintenance. When this approach is used, the agency contracts for the acquisition of a function (or capability) rather than a specific system. There is increasing interest in this approach as a result of the shortage of skilled individuals capable of managing the acquisition, operations and maintenance of a complex system. As a result, outsourcing is included as a procurement alternative.

**Low-bid procurement is applicable only to extremely well-defined projects.** Analysis of the systems engineering requirements of ITS procurements identified collaboration between contractor and agency personnel, participation in the planning process, flexibility in definition of functions and iterative system developments as key features of a successful project implementation. It is difficult, if not impossible, to incorporate these activities into a low-bid procurement. For this reason, the guidelines recommend that low-bid procurements only be used for acquisition of systems with well-defined capabilities by agencies with the experience to manage its implementation.

**It is essential that projects be structured in a manner that provides direct access to the contractor performing the high risk portions of the work. This may lead to the need for multiple contracts.** The organization of the contractor's team has been shown to be one of the shortcomings of projects that have experienced difficulties. It was concluded that one of the ingredients of a successful project is the ability of the agency's project engineer to interact directly with the contractor whose work represents the highest risk to the project's success (i.e. the system software). It was concluded that projects requiring extensive software development, must be organized such that the contractor responsible for the software development is the prime contractor. In the event that the overall project requirements prevent this form of organization under a single contract (i.e. the software has a low dollar value relative to the overall contract), the guidelines suggest that the project be divided into multiple contracts. The software developer should be the prime contractor for one of these contracts.

**Project planning is a frequently overlooked step in the system development process.** Project planning encompasses a number of activities that are critical to the system procurement and acquisition process. Yet these activities are rarely (if ever) performed. The research concluded that all procurements should be preceded by the definition of project scope, a careful cost estimating process, and the development of a work breakdown structure with schedule for the system procurement. These activities should be documented in a procurement plan, and a project management plan that can be used as the basis for the system acquisition.

**The contracting statement of work must ensure that responsibilities for performing all systems engineering activities are fully identified.** The definition of the systems engineering process prepared for this research identified a number of cross-cutting activities that are critical to the overall success of the system acquisition. These activities include: risk management, configuration management (including the establishment of a configuration control board) and quality assurance. Responsibility for these “cross-cutting” activities should be defined in the contractor’s scope of work. They are described in the guidelines.

## **CHAPTER IV**

### **CONCLUSIONS AND SUGGESTED RESEARCH**

#### **ENCOURAGE USE OF GUIDELINES AND DISSEMINATE THE RESULTS**

The guidelines prepared for this project represent a breakthrough in the ITS community's understanding of the interrelationship among organizational experience and resources, project characteristics and procurement techniques. It is unlikely that any new techniques and procedures will be integrated into the accepted practices of the profession unless their use is actively encouraged. For this reason, it is recommended that an aggressive outreach campaign be developed and executed with the support of the American Association of State Highway and Transportation Officials (AASHTO), ITS America, and the National Transportation Operations Coalition (NTOC) that includes:

- Preparation and dissemination of brochures and other announcements intended to inform the profession of the availability of this research and the potential benefits of its use
- Preparation and delivery of training courses (either on-line or classroom) to instruct ITS professionals on the use of the guidelines
- Integration of the guidelines into existing curricula of the Federal Highway Administration's Professional Capacity Building Program including existing systems engineering and project management courses. Training should also be provided to FHWA field personnel regarding the availability of the guidelines and their application to the ITS procurement process.
- Inclusion of papers and presentations describing this work at national conferences sponsored by ITS America, the Institute of Transportation Engineers and NTOC.
- Offers of assistance through the FHWA Peer-to-Peer program, to agencies contemplating ITS procurements. This requires provision of prior training to Peer-to-Peer personnel in the use of the guidelines.

#### **PILOT TEST GUIDELINES**

Testing of the guidelines should be conducted, using a sample of upcoming ITS procurements. Testing should be performed for a variety of procurements including systems development and outsourcing, small systems and large systems, field construction and central system installations. The testing should include documentation of the processes used, the conclusion of the process and the success of the system implementation.

#### **RESEARCH IMPACT OF ORGANIZATIONAL STRUCTURES ON ITS PROCUREMENT**

During the research it became evident that organization structure can have a significant impact on the success of the ITS system procurement as well as the overall implementation

process. Organizations in which the functions of planning, engineering (design), construction, operations and maintenance are integrated tend to have a better record of success, than organizations in which these functions have been segregated into independent units (stovepiped). More information on the relationship between organization and system development risk is required. It is necessary to identify the range of organizations that currently exist within State DOTs, and evaluate their relative success in the system acquisition process. It is recommended that research be conducted in this area.

## **INTEGRATE GUIDELINES INTO SYSTEMS ENGINEERING PROCESSES**

Predictably, this project concluded that the procurement and systems engineering process are interdependent on each other. One of the conclusions of this project that the combination of agency and project characteristics could be used, not only to define the procurement approach, but to identify the most suitable systems engineering process. These results should be integrated into the systems engineering training material and other reports used by the ITS community for systems implementation.

## **GLOSSARY OF TERMS**

<b>Acquisition</b>	The overall process of implementing a system, including planning, procurement, design, development, testing and acceptance.
<b>Best Value</b>	A form of contractor selection based on both the quality of the contract and cost.
<b>Burden</b>	A percentage charge applied to the direct contract costs that cover the contractor's cost of doing business. Typical burden items include overhead (rent, office supplies, business expenses, office equipment, legal expenses, etc.), fringes (employee benefits - including sick leave, vacation, health insurance, etc.), general and administrative costs (management costs).
<b>Certification</b>	The formal acknowledgement (usually provided by an independent organization) that a contractor has certain capabilities and procedures required for a particular purpose. Certification may be required as part of a pre-qualification process.
<b>Collaboration</b>	A close working relationship between the customer and the supplier that permits the exchange of ideas and joint resolution of problems associated with a project.
<b>Commodity</b>	A commodity is a product as distinguished from a service
<b>Commodity Supplier</b>	A supplier from which commercial off-the-shelf products (including software) are being purchased.
<b>Consultant</b>	A contractor whose work is limited to personal services. Consultants do not supply construction services and/or equipment.
<b>Contract</b>	A written agreement between two parties (in this case it is assumed that the parties will be the agency and an outside organization – usually a private sector firm) that is an agreement for doing or not doing something that is specified.
<b>Contract Form</b>	As used in these guidelines, the manner in which work is authorized during the contract period of performance.
<b>Contract Type</b>	As used in these guidelines, the manner in which contractors are reimbursed for their work.
<b>Contracting</b>	The selection of a firm to provide a set of services or products, as well as negotiating and executing a contract.

<b>Contractor</b>	This term is used in two different ways. The general use of this term is that the contractor is an organization with which a contract has been signed. This general terminology can include a design contractor (consultant), software company, systems integrator, electrical contractor, construction contractor, etc. When the Consultant/Contractor form of work allocation is discussed, the term contractor is a reference to an organization that has been selected (usually on a low-bid basis) to implement a system specified by a consultant. To avoid confusion in the discussion of this form of work allocation, the organization selected in this manner will be referred to as a low-bid contractor.
<b>Cost Reimbursable</b>	A form of reimbursement in which the contractors are paid the actual cost of performing the work, plus a fee that may be a fixed amount, or may be adjusted based on the quality of the contractor's performance.
<b>Design-Build Contract</b>	A form of contract in which the contractor is given responsibility for both the system design as well as its implementation
<b>Design-Build Operate and Maintain</b>	A design-build contractor (see definition) who has also been given responsibility for operations and maintenance once the system development has been completed.
<b>Direct Costs</b>	Expenses directly attributable to work performed on a project, as opposed to indirect costs, which are unrelated to specific projects.
<b>Evolutionary Model</b>	A systems engineering methodology in which the system is implemented incrementally. The steps of design, development and testing are repeated for each incremental "build".
<b>Fee</b>	Synonymous with Profit. The fee (or profit) is the payments received by the contractor in excess of contract costs and burdens that are value-added compensation for performing the work.
<b>Fixed Price</b>	A form of reimbursement in which the contractors are paid a fixed amount, independent of the actual costs of performing the work, based on an initial cost estimate
<b>Incentive</b>	An additional fee paid to the contractor based on pre-defined criteria
<b>Indirect Costs</b>	Expenses of doing business that cannot be directly attributable to a specific project. Examples of indirect costs include office space, advertising, employee fringe benefits, etc.
<b>Invitation for Bids</b>	A document released by a procuring agency requesting bids for services, equipment and/or commodities from potential contractors. A contract is awarded to the lowest responsive and responsible bidder.
<b>Invitation to Negotiate</b>	A contractor selection process that includes a series of steps in which work scope is adjusted based on vendors proposals.

<b>Low-Bid</b>	The process of competing for work defined by a set of plans and specifications based exclusively on bid price. The competitor with the lowest bid price is selected for the project.
<b>Method of Award</b>	As used in these guidelines, the process by which a contractor is selected during a competitive procurement
<b>Negotiated Procurement</b>	A process by which all procurement terms are discussed and may be reconsidered by the purchaser and the offeror. These terms may include requirements, specifications, period of performance, location of work, scope of services, staffing requirements, etc. Negotiated procurements typically reflect a discussion of non-financial considerations prior to the discussion of the proposed contract cost although this “two step” evaluation is not always required.
<b>Negotiated Selection</b>	A selection process in which a contractor (usually a consultant or systems manager) is selected based on the quality of a proposal which describes the contractor’s capabilities, staff skills, technical approach and prior experience. Negotiated selections usually do not include consideration of cost.
<b>Outsourcing</b>	A form of contract in which the contractor’s responsibilities are defined based on managing or maintaining certain aspects of an agencies’ business.
<b>Performance-Based Contracting</b>	A contracting process in which the contractor’s compensation for work on the contract is partially dependent on the success of the project.
<b>Phased</b>	A contract in which work is divided into stages. Typically each stage cannot begin without prior authorization of the agency.
<b>Pre-Qualification</b>	The process of assessing a contractor’s ability to perform the required work based on past experience and staff skills. Pre-Qualification is often a step that precedes the proposing or bidding process of procurement, and must be satisfied by the contractors in order for them to participate in the process.
<b>Procurement</b>	The process of selecting a contractor and negotiating a contract for delivery of a services and/or products. Procurement is a subset of the system acquisition process. Same as contracting
<b>Purchase Order</b>	An offer by the procuring agency to buy supplies or services, including construction and research and development, using specified terms and conditions.

<b>Request for Proposals</b>	A document released by a procuring agency asking for the submission of proposals for personal services from interested consultants. A document that is released to prospective contractors in connection with a negotiated procurement that defines the agency's requirements.
<b>Sole Source</b>	A contract that is awarded without competition.
<b>Spiral Model</b>	A systems engineering methodology in which system requirements are developed based on extensive prototyping and analysis.
<b>Statement of Work</b>	A description of the services and products to be provided by a contractor along with the contractor's overall responsibilities in connection with these items. The Statement of Work is contained both in the request for proposals and the contract. Also known as Work Scope
<b>Systems Integrator</b>	A contractor assigned responsibility for providing all personal services required for system development. This may include software development, systems integration, inspection and testing.
<b>Systems Manager</b>	A contractor assigned responsibility for providing all personal services required to implement a project. Systems managers may be given responsibility for system planning, design, software development, systems integration, inspection and testing.
<b>Task Order</b>	A contract form in which work assignments are divided into tasks that are defined once the contract is underway. Task order contracts require the agency to release a task order to the contractor. The contractor responds with a brief proposal and cost estimate. If the contractor's submission is acceptable, work on that task is authorized.
<b>Terms and Conditions</b>	Contract requirements that define all of the responsibilities of both parties to the contract except for the work to be performed.
<b>Time and Materials</b>	A form of reimbursement in which contractors are reimbursed for the actual cost of performing the work plus a fee that is a percentage of the reimbursed costs.
<b>Waterfall Model</b>	A systems engineering methodology in which the project planning, design, implementation and testing steps are performed sequentially
<b>Work Allocation</b>	As used in the guidelines, work allocation refers to the assignment of responsibilities to various project team members including the agency, contractors and consultants

## ACRONYMS

<b>CCTV</b>	Closed circuit television
<b>COTS</b>	Commercial off the shelf
<b>DBOM</b>	Design-Build Operate and Maintain
<b>DMS</b>	Dynamic Message Sign
<b>DOT</b>	Department of Transportation
<b>IFB</b>	Invitation for Bids
<b>IT</b>	Information Technology
<b>ITN</b>	Invitation to Negotiate
<b>ITS</b>	Intelligent Transportation Systems
<b>RFP</b>	Request for proposals
<b>SOW</b>	Statement of Work
<b>TSMO</b>	Transportation Systems Management and Operations

## **APPENDIX A: REFERENCES**

## **APPENDIX B: DETAILED SURVEY RESPONSE**

## **APPENDIX C: ITS PROJECT CATEGORY WORKSHEET**

## **APPENDIX D: AGENCY CAPABILITY WORKSHEET**

## **APPENDIX E: TASKS 1 AND 2 WORKING PAPER**

## **APPENDIX F: TASK 3 WORKING PAPER**

## **APPENDIX G: TASK 4 WORKING PAPER**

## **APPENDIX H: TASK 5 WORKING PAPER**