Task 3 Working Paper

to the

National Cooperative Highway Research Program (NCHRP)

on Project 03-77
Guide to Contracting ITS

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TABLE OF CONTENTS

BACKGROUND

The successful acquisition of Intelligent Transportation Systems (ITS) has proven to be a challenge for state and local transportation agencies alike. The challenge has been more institutional than technological in nature. Many of the institutional challenges standing in the way of deploying ITS can be attributed to ITS procurement. The American Association of State Highway and Transportation Officials (AASHTO) through the National Cooperative Highway Research Program (NCHRP) has initiated the development of a Guide to Contracting ITS Projects (Project 03-77). The scope-of-work (SOW) associated with the development of this guide is outlined below[1]:

- Task 1 – Review of Transportation and Technology Literature
- Task 2 – Look at Other Industries
- Task 3 – Categorize ITS Projects
- Task 4 – Systems Engineering Process
- Task 5 – Recommend Contract Types
- Task 6 – Prepare a detailed Outline of the Guide
- Task 7 – Prepare the Guide
- Task 8 – Submit Final Report

This working paper provides a summary of the work completed for task (3). This paper also presents results that will be used as the basis for the work in tasks (4) and (5). This is considered a draft deliverable that will be finalized based on input received from the NCHRP panel overseeing this project.

INTRODUCTION

The purpose of task 3 is to categorize ITS projects based on a number of factors[2] 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[3]. 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 in the detailed SOW for this NCHRP project provided a starting point for identifying generic ITS project categories along with the factors and characteristics that support their definitions ***(see Table 1 on following page)***. The "starting point" included

[1] A detailed SOW for this NCHRP project is included in the proposal.
[2] These are the original factors as listed in the NCHRP Project 3-77 Request for Proposal.
[3] *Intelligent Transportation System (ITS) Software Integration Project Risk Assessment and Mitigation*, 2002, Yermack, Larry, and Iserson, Andy, prepared for AASHTO.

Table 1. ITS Project Categories and Associated Characteristics

	Category 1	Category 2	Category 3	Category 4
Complexity	Simple	Moderately complex	Complex	Extremely complex
Level of New Development	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 exisitng 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
Scope & Breadth of Technologies	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
Interfaces to Other Systems	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
Technology Evolution	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 signifcant impact and must be adequately accounted for in system design	Technology evolution very likely with potential major implications on system to be implemented
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 processess	System requirements not well defined, understood, and very likely to change over time. Requires strict adherence to formal requirements management processes
Overall Risk	Low	Moderate	High	Very high
General ITS Project Example	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.

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.

The intent of the work on task 3 to date has been to validate 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[4] that can best address the overall risk associated with and ITS project.

[4] Recall that the four dimensions of procurement that were identified in tasks (1) and (2) include: Work Allocation, Method of Award, Contract Form, and Contract Type.

PROCESS

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[5] 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 effort, including an updated version of Table 1, are discussed in the next section.

RESULTS

The table in Appendix A maps the 19 project examples to the factors and associated characteristics in Table 1. This mapping process revealed that the ITS project categories, factors, and associated characteristics originally developed for Table 1 under the statement of work, were largely on the mark. The exceptions, which have resulted in modifications to Table 1, are as summarized as follows:

[5] System types were based on the organization of US DOT's ITS Projects Handbook.

- **ITS Project Factor Modification.** A new ITS Project Category factor called "Institutional Issues" has been added. As ITS projects were reviewed for inclusion in the table in Appendix A, it became clear that there was an important factor missing that, while non-technical in nature, has a great deal of influence on the difficulty associated with implementing an ITS project. The "Institutional Issues" factor is intended to help describe an ITS project in terms of, for example, the need for new agreements (either intra or inter agency Memorandum of Understanding), modifications to existing business models, working relationships, or operational procedures, and a general need to work with non-traditional partners.

- **Modifications to the Factor Characteristics.** The following key modifications have been made to the characteristics that describe the factors:

  - The characteristics of the factor "Scope and Breadth of Technologies" now include the concept of "phasing". In terms of scope, an ITS implementation may be done as a single stand-alone project. At the opposite end of the spectrum, a very large ITS project may be divided up into multiple phases. The degree to which phasing is used will impact an agency's procurement strategy.

  - The characteristics of the factor "Technology Evolution" have been expanded and clarified. In preparing the Table in Appendix A, this was the most difficult factor in trying to relate to a real-world ITS project and it became abundantly clear that the characteristics describing this factor in Table 1 were too vague. Task 3 of the RFP for NCHRP Project 3-77 describes this factor as "likelihood of technology evolution." 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 (or in some cases by the time the RFP hits the streets). 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[6]. The characteristics describing the Technology Evolution factor have been modified to describe a subjective perspective of the perceived impact of Technology Evolution on software and hardware deployed under an ITS project. In this perspective, technology evolution is perceived by the deploying agency or organization as being a relatively minor issue for a Category 1 ITS project whereas it becomes an increasingly bigger issue as the category increases.

[6] Association for Information Systems (AIS)

- The factor characteristics in Table 1 were very much software oriented. They have been modified to include a hardware orientation as well.

All of these modifications are reflected in an updated ITS Project Category Table ***(see Table 2 on the following page)***. Following is a summary of the descriptive characteristics for the category factors that have been updated, as appropriate, from what was included in the original statement-of-work.

- **Complexity.** The characteristics that describe this factor provide a succinct indication of 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. The description of "Simple" for a Category 1 project in Table 1 was changed to "Straightforward" in Table 2.

- **Level of New Development.** The characteristics that describe this factor describe the level of new software development and hardware deployment associated with an ITS project implementation. The level of new software development typically is the riskiest factor 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 interfaces to transit, public safety, and commercial vehicle systems and databases, implementation of wire-line and wireless communications technologies, etc. Another scope related characteristic that was added 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 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.

Table 2. Updated ITS Project Categories and Associated Characteristics

	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 exisitng 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.	Primarly 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 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 signicant 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.
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 technolgy 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 extentable 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 is interoperable. Ramifications of not using standards based technolgy 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 extentable 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 processess.	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 particlar department within the agency.	Minor- may involve coordination between two agencies. Formal agreements not necessarily required, but if so, agreements are already in place.	Signficant- 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 muli-agency project oversight organization.
Overall Risk	LOW	MODERATE	HIGH	VERY HIGH

- **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. This "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 in 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. 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 easily deploy standards based hardware from different vendors in the future. When it comes to category 3 and 4 projects, the need for taking into account technology evolution should be based less on the 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). 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 help 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.

CONCLUSIONS & RECOMMENDATIONS

One drawback to Table 2 is that it emphasizes only the ITS project specific factors and characteristics associated with a project implementation. While an understanding of these 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 applied on a successful ITS implementation. Figure 1 identifies the additional factors that will influence selection of an appropriate procurement strategy. The factors in the middle box on the left side of the diagram are those that are included in Table 2 and have received the attention of this task to date. The "Agency" box and "Environment" box identify additional non-project specific factors that will directly influence procurement decisions. These additional factors span all ITS Project Categories and are summarized as follows:

- **Agency Factors.** These factors and associated characteristics generally pertain to an agency's (or organization's) capability to successfully manage an ITS project implementation. Agency factors include:

  – **Personnel.** It is critical that an agency, to the extent possible, have the necessary personnel with the appropriate 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, electrical engineers, 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.

- **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.

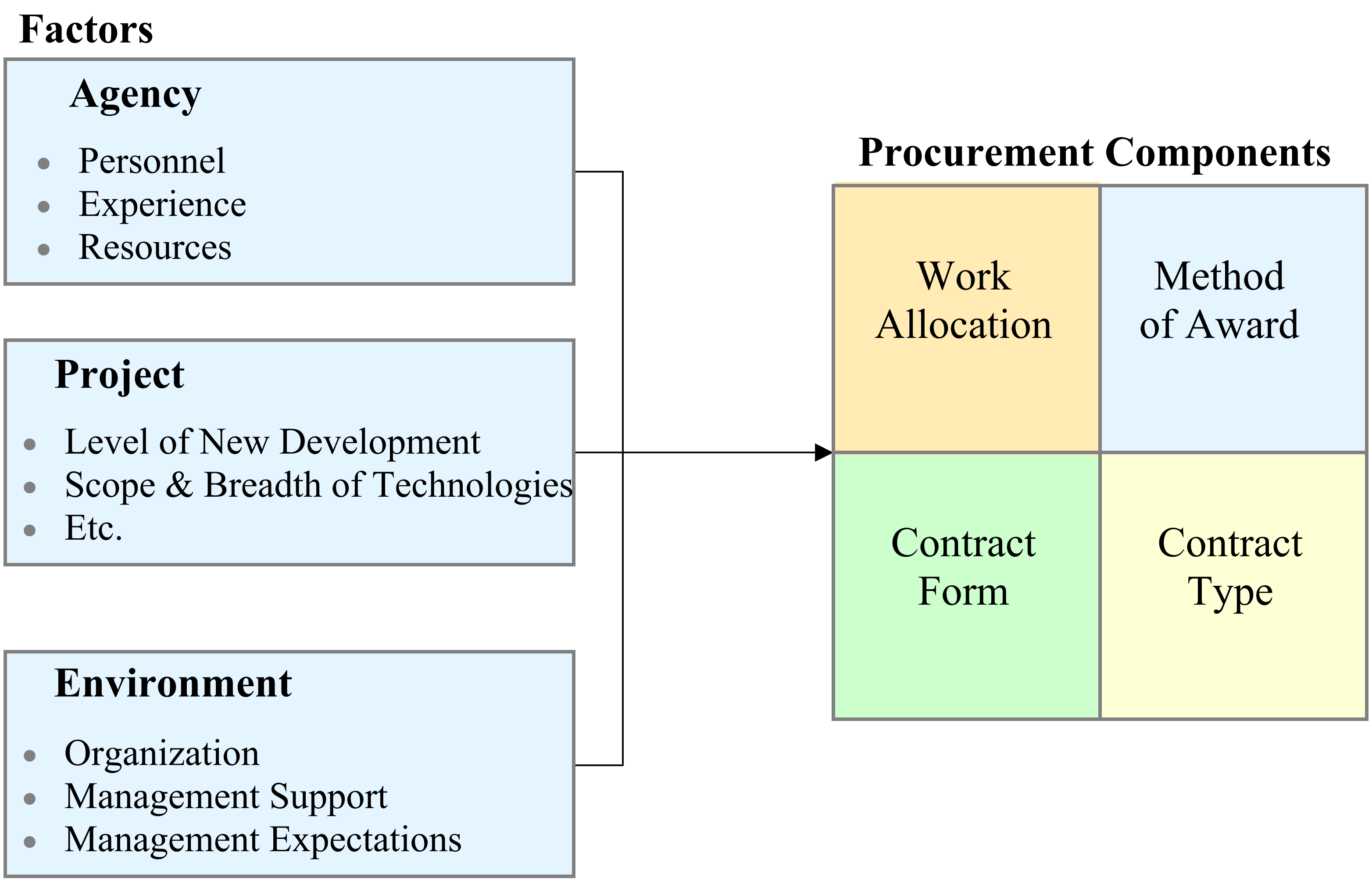
- **Resources.** An agency needs many types of resources to achieve a successful ITS implementation. Personnel, funding, office space and equipment, and training represent just a few examples of these important resources. Obviously funding is important, but if funds are available, personnel resources are perhaps the most critical.

- **Environmental Factors.** These factors and associated characteristics generally pertain to the overall environment or organizational culture within which an ITS project is implemented. Factors related to environment include:

  - **Organization.** 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.

  - **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.

Figure 1. Factors Influencing Procurement

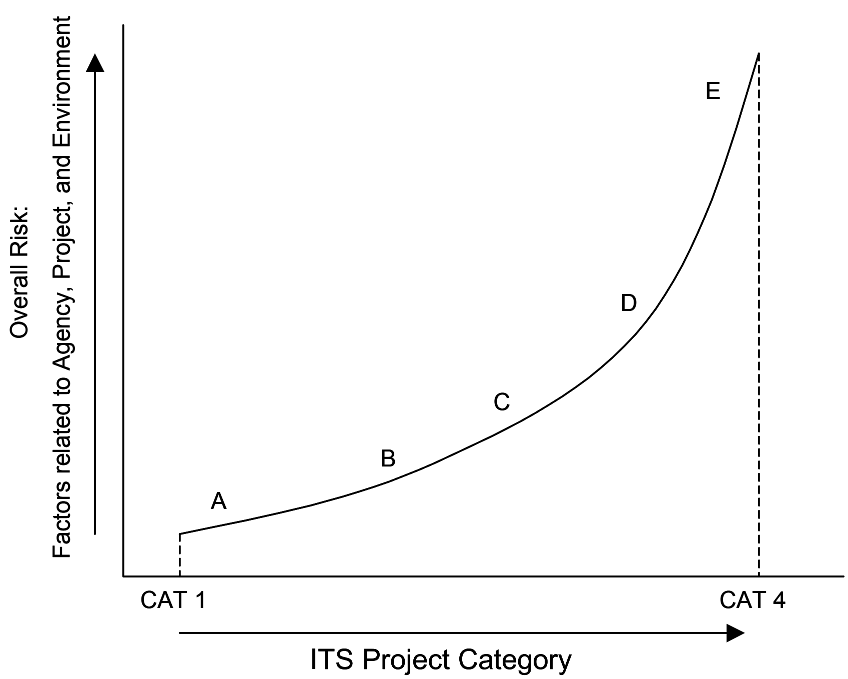


– **Managing Expectations.** This factor can make or break an ITS project. Managing expectations means not over promising, especially with regard to functionality or the time frame under which functionality will be deployed.

It is apparent then that the overall risk of an ITS project is really based on a combination of all three subsets of factors included in Figure 1, Agency Factors, Project Factors, and Environmental Factors. ***Figure 2*** shows that as the ITS Project Categories go from straightforward (Category 1) to extremely complex (Category 4), the overall risk based on Agency, Project, and Environmental factors increases (note that the curve representing this relationship is illustrative only). The combination of all of these factors, together with the concept of ITS categories, may be used to determine the appropriate mix of procurement components. This mix of components is represented by the box divided into four quadrants (Work Allocation, Method of Award, Contract Form, and Contract Type) on the right side of Figure 1. This mix of components as represented by the box on the right side of Figure 1 is analogous to the letters A,B,C,D,E along the curve of Figure 2. For example, the point on the curve represented by letter A may represent the following mix of procurement components based on a relatively straightforward low risk ITS project:

- Work Allocation: Contractor
- Method of Award: Low Bid
- Contract Form: Phased
- Contract Type: Fixed Price

Figure 2. ITS Project Category vs. Overall Risk



However, the point on the curve represented by letter E would represent and entirely different mix of procurement components based on an extremely complex high risk ITS project. This mix might be as follows:

- Work Allocation: Design-Build
- Method of Award: Best Value with Negotiations
- Contract Form: Task Order
- Contract Type: Fixed-Price with Incentives

The letters are illustrative only, however, the intent is to show that the mix of procurement components will vary as appropriate to address the complexity and risk associated with an ITS implementation.

It is worth noting that describing an ITS project by its associated “Category” is not in itself inherently useful. While Table 2 has clearly delineated lines separating the four categories, the reality is that the lines separating categories can be blurred. For example, a project may have characteristics that equate to some factors being associated with a Category 1 project, some with a Category 2, and perhaps one with a Category 3 or 4. The problem then becomes a matter of choosing a category. However, the category is not, by itself, important. What is important are the actual factors and associated characteristics. It is recommended that the factors and associated characteristics in Table 2, along with the non-project specific factors and characteristics that have been identified, be used as the basis for carrying out work under tasks 4 and particularly 5, where contract types are to be recommended. The results of task 3 will also serve as the basis for providing the input to a prototype of a web-based tool that will assist an individual in determining the appropriate mix of procurement components (output) based on their project, agency, and environment.

Appendix A

Example ITS Projects

Appendix - Example ITS Projects

ITS Project Description	Category	System Type	Complexity	Level of New Development	Scope & Breadth of Technologies	Interfaces to Other Systems	Technology Evolution	Requirements Fluidity	Institutional Issues	Overall Risk	Remarks
CCTV system expansion on I-85 and I-95 in SC	Category 1	FMS	Straightforward	Implementation of commercially available hardware and software based on existing system	Scope and breadth limited in that project included installation of CCTV cameras (based on previously used hardware). Stand-alone project was done in a single phase.	Field hardware interfaced to existing TMCs. No new system interfaces.	Compatible (e.g. same vendor) CCTV system hardware / software is used. Perceived need to account for technology evolution is minor.	Since system install based on CCTV technology previously used, requirements were well understood.	minimal	LOW	
Install additional transponder readers on Belt Parkway, Van Wyk, Cross Island, etc. (TRANSMIT)	Category 1	FMS/ETC	Straightforward	This project was based on installing additional existing commercially available transponder reader hardware. Software for processing tag data had already been developed.	Scope and breadth limited in that project involved installing additional field devices [based on previously used hardware and typical field installations of reader devices mounted on existing structures]. Single phase implementation.	Field hardware interfaced to existing data collection / processing system.	Readers installed based on existing / previously used specifications to read existing toll-tags. Perceived need to account for technology evolution is minor.	Since reader installations are based on previously used technology and typical field installations, requirements were well understood.	minimal - all installs were in NY State, some coordination required between NY State DOT and NYC DOT	LOW	Could be future technology evolution issues based evolving 5.9 GHz DSRC standards.
Install 8 RWIS sites in Anchorage	Category 1	WS	Straightforward	Initital installation (Phase 1) in Anchorage Bowl area involved COTS road weather information system including hardware and software.	Scope and breadth limited to installing commercially available hardware and software for 8 RWIS sites. This was the first phase of a multi-phase initiative.	Installation of stand-alone RWIS…no interfaces to other system(s) for initial install.	According to manufacturer, RWIS installed based on "open-architecture" and field equipment NTCIP-ESS compliant.	Commercial RWIS have been available for many years. Requirements for typical installations of these sytems are well understood.	minimal	LOW	Phase 2 included expansion of sites statewide with remote sites having difficult implementation issues (e.g., power & comm). Phase 2 also included participation in AURORA[1]. Phase 2 would likely be considered a Category 2 project.
Place 75 portable DMS in Metro Boston Area	Category 1	FMS	Straightforward	Purchase and installation of commercially available portable Dynamic Message Sign hardware and software.	Scope limited to purchase of specific hardware and software. Portable DMS placed at strategic decision points within Metropolitan Boston Area.	Purchase and install of stand-alone portable DMS…no interfaces to other systems.	Compatible (e.g. same vendor) DMS hardware / software is used. Perceived need to account for technology evolution is minor.	Commercially available portable DMS have been available for many years. Requirements for this equipment and its uses are well understood.	minimal	LOW	Today, technology evolution with regard to DMS can be somewhat addressed through specifciation of NTCIP DMS standards.

Appendix - Example ITS Projects

ITS Project Description	Category	System Type	Complexity	Level of New Development	Scope & Breadth of Technologies	Interfaces to Other Systems	Technology Evolution	Requirements Fluidity	Institutional Issues	Overall Risk	Remarks
Install closed-loop signal system covering 75 intersections in Kinston, NC	Category 2	AMS	Moderately Complex	Purchase and installation of commercially avialable signal control hardware and closed-loop control software. Project included installation of a few CCTV cameras as well.	Predominately installation of proven, well known, and commercially available hardware and software. Incorporation of both signal control and CCTV camera systems. Single phase implementation.	Control software interface to field devices COTS-based. No interfaces to other non-signal control systems.	Compatible (e.g. same vendor) hardware / software is used. Standards based traffic controllers implemented. Possible technology evolution issues if future desire to operate in a non closed-loop environment (e.g., adaptive control).	Requirements for closed loop signal control are well understood and there are a variety of COTS hardware/software systems available to meet these requirments. Inclusion of CCTV camera monitoring requires a bit more attention to requirements gathering.	minor - some coordination between NC DOT and City of Kinston, but predominately a NC DOT project	MODERATE	
Install smart work zone systems at 5 Interstate work zones in Arkansas	Category 2	FMS/IMS	Moderately Complex	Purchase and installation of commercially available Automated Work Zone Information Systems (AWIS) from multiple vendors.	Predominately installation of relatively proven commercially available hardware and software. Single phase implementation, but involved separate construction contracts.	Each AWIS was installed as stand-alone system (by requirement). No interfaces to other systems or a centrol control system in a Traffic Operations Center.	Compatible (e.g. same vendor) hardware / software is used for each AWIS site. Perceived need to account for technology evolution is minor. Likely issue is that equipment software implemented by different vendors is incompatible.	Requirements generally well understood. Additional attention to requirements based on fact that no TOC in Arkansas to monitor/control AWIS.	minor - design, installation, and operation of smart zone system made responsibility of construction contractor.	MODERATE	
Expand FMS/EOC in Baton Rouge, LA	Category 2	FMS	Moderately Complex	Expansion of FMS field equipment and installation of fiber optic backbone communications. Field equipment (e.g., CCTV, detectors, DMS, etc.) based on previously used equipment and exisiting COTS-based central control software.	Wide array of field hardware deployment (CCTV, DMS, detectors, HAR, etc.) and fiber optic communications over 15 miles of I-10 in urban area. Field hardware technology well known and commercially available. Multi-phase implementation.	Interfaces between field equipment and central software based on previously used hardware and central software. No interfaces to other systems.	Compatible hardware (based on previously used specifications) / software (based on existing central software) used during implementation. COTS standards based central software capable of controling multiple ITS field devices.	Requirements generally well understood based on installation of typical FMS field equipment. Additional attention to requirements based on transition to fiber backbone for field device communications.	minimal- expansion of existing jointly operated FMS/EOC in which may institutional issues already resolved.	MODERATE	
Install software that allows communication with multiple existing portable DMS in North Dakota	Category 2	RTM/RTIS	Moderately Complex	Implementation of software that will allow control of DMS hardware from several different vendors. Involved examination of COTS software that could be used for this purpose.	Software implementation for control of portable DMS used throughout state in winter for traveler information and summer for construction. Scope and breadth limited to single software application for controlling similar field hardware. Single phase implementation.	No interfaces to other systems involved.	Not an issue if portable DMS from same vendor(s) continue to be purchased. Could become an issue if DOT would like to use DMS from another vendor that is not currently used. DMS standards issues a consideration.	Requirements well understood. If COTS application does not work and new software is developed, requirements management becomes more of an issue.	minimal	LOW-MODERATE	

Appendix - Example ITS Projects

ITS Project Description	Category	System Type	Complexity	Level of New Development	Scope & Breadth of Technologies	Interfaces to Other Systems	Technology Evolution	Requirements Fluidity	Institutional Issues	Overall Risk	Remarks
Maintain ITS Equipment in Virginia I-81 Corridor	Category 2	O&M	Moderately Complex	No new development. Performance based ITS field equipment maintenance support services.	Scope limited to field ITS hardware failure maintenance and preventive maintenance. Technologies include DMS, CCTV cameras, HAR, RWIS stations, etc.	No interfaces to other systems involved.	Unlikely to be an issue as project involves maintenance of existing field equipment.	Requirements unlikely to change over time; however, developing initial performance requirements can be challenge.	minor - use of performance specifications of prescriptive specifications. Requires good data collection procedures for measuring outcomes agains goals.	MODERATE	
Integrate operations of fixed-route and demand-response paratransit systems in Brownsville, TX	Category 3	TMS	Complex	COTS based applications of AVL and dispatching / transit management center software and transit fleet hardware.	While transit operations are relatively small, the scope and breadth signficant including software and hardware to implement AVL, center to fleet communications, passenger counting, dispatching, and real-time web-based transit information. Multi-phase implementation.	Involves integration of fixed route and demand-response paratransit systerms. Other interfaces to non-transit related transportation and public safety systems are under consideration.	Technology evolution a significant issue as project involves signficant software, hardware, and mobile communication issues.	Transit management system requirements are well understood and there are COTS based applications available. However, project scope, and potential for technology evolution require early definition of requirements. Formal requirements management a consideration do to potential for evolving requirements.	Significant - project involves combing operations of fixed route and paratransit into centralized transit operations center. Interfaces to other public safety systems may require formal agreements.	HIGH	

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Develop statewide transit trip planning web-site that covers Washington and Oregon	Category 3	TIS/TMS	Complex	Possible combination of existing COTS software implementation and new software development. Will assess to extent COTS can meet requirements.	Scope involves development of comprehensive statewide transit trip planning system covering over 200 public transportation providers across state. Breadth is initially focused on transit trip planning put there are plans for future features such as electronic fare payment and wireless/PDA support. Multi-phase implementation.	System must interface to many existing transit systems. Plans underway to integrate Oregon system with similar transit trip planning system developed separately by Washington DOT.	Technology evolution an important issue as there are a number of systems to be interfaced that will involve changing / advancing technology. Determing how to design for initial application while keeping mind future anticipated functionality is important.	Complex project likely involving new software development will require early emphasis on developing requirements and a formal requirements management process throughout the development effort.	Significant institutional hurdles to overcome considering number of existing transit service providers and desire to integrate with adjacent state DOT effort to be developed under separate contract.	HIGH	
Install EZ-Pass ETC system on New Jersey Turnpike	Category 3	ETC	Complex	Implementation of previously existing and proven ETC hardware. Some development required to account for variable distance-based toll.	Application of proven well known hardware based on existing EZ-Pass installations throughout North East. Geographic scope considerable as initial plance called for equipping 344 toll lanes with ETC technology. Multi-phase implementation.	Interface to existing EZ-Pass centralized financial clearinghouse well known.	At time of implementation, technology evolution not a large issue as specifications for existing reader equipment and toll tags based on existing systems and need to be compatible.	Hardware and related field installation requirements well known. Back-end processing software requirements less know as system had to be designed to account for distance based tolls.	Significant - becoming part of EZ-Pass Inter-agency Group (IAG) and becoming part of EZ-Pass Business model issues that were overcome	HIGH	Could be future technology evolution issues based evolving 5.9 GHz DSRC standards.
Implement AVL and automated scheduling, disptaching, and billing software covering three transit systems in three counties in north Florida	Category 3	RTranM	Complex	Implementation of COTS based software and hardware from multiple vendors.	Implementation of COTS GIS-based routing software, cellular-based AVL system and COTS based AVL software and mobile computing hardware from another vendor. Multi-phase implementation.	No interfaces between existing systems; rather interfacing accomplished through purchase and deployment of same GIS-based routing software.	Technology evolution not considered major issue during implementation, but could become issue in future as agencies look to expand capabilities and functionality.	Use of COTS software and hardware, however, effort required more time spent developing operational requirements for all involved operating agencies.	Significant - coordination of deployment among four rural tranist agencies a signifcant issue. Lack of staff / expertise issue during system installation.	HIGH	

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Develop map-based ATMS control software for LA TMC and install as state standard in 12 other rural and urban TMCs in California	Category 3	FMS	Complex	Implemention of developed TMC software in state TMC's as standard operating system.	Involves implementation of developed softare and recommend standard COTS hardware. Software functionality is for control of all ITS field devices and will allow distributed access to devices among state TMCs. Software functionality deployed in phases.	State TMC interfaces through deployment and use of compatible standard central software.	Technology evolution of field devices and state based standard software functionality a signficant issue.	Development of software used as state standard requires formal requirements management process.	Internal coordination amongst all involved districts a signficant instituional issue.	HIGH	
Install PrePass system at 20 weigh stations and electronic one stop shopping system in Illinois	Category 3	CVO/CVISN	Complex	Implementation of existing, proven COTS software and hardware.	Implementation of proven well known hardware based on existing roadside applications. Techologies include transponders, readers, and WIM. Site deployment involved multiple phases.	Interface to existing state safety and registration databases required to verify compliance.	System hardware and software based on COTS. Equipment specs defined based on need to be compatible with over 240 operational sites across the U.S. Possible future issue with advent of DSRC standards.	Hardware and related field installation requirements well known. Attention to specific requirements for interface to state systems requires attention to some level of requirements definition and management.	Issue of who gets to by-pass. Only carriers with proven safety records can particpate.	MODERATE-HIGH	
Construct and activate Statewide Operations Center in KY including Public Safety dispatching and back-up EOC functionality	Category 4	FMS/PS/EM	Very Complex	Implementation of a combination of existing and new central software along with new COTS hardware.	Involves construction of new facility, integration of new hardware and software. Functions include traveler info, DMS, CCTV control, RWIS, and centralized dispatch for all KY vehicle enforcement uniformed officers. Multi-phase implementation.	Includes interfaces to existing systems such as RWIS and the Condition Acquisition Reporting System (CARS), public safety disptach system, and plans for state-owned signal systems.	Technology evolution a major issue as field hardware and existing system software will have impact on central system software.	Size and complexity of projects requires formal requirements management process.	Major - Institutional issues related to forming partnership with public safety to include dispatch operations in TOC.	VERY HIGH	

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Deploy region wide SmarTrip fare payment system in metropolitan Washington, D.C.	Category 4	EFPS	Very Complex	Involves upgrade of existing system software to include a newer generation fare collection system.	In addition to upgrade of existing system software, involves development and implementation of central database to collect transaction data from 16 partner agencies and point-of-sale network. O&M also included for customer service, card management, transaction clearing and settlement, etc. of Regional Customer Service Center (RCSC). Multi-phase implementation.	Doesn't include interfaces to other agency systems, but does include establishing POS network with compatible equipment and separate purchase and installation of compatible fare collection equipment by regional partner agencies.	Technology evolution a major issue to contend with. For POS equipment, a proprietary card-to-reader interface is necessary to operate with the legacy SmarTrip system, but system is upgradable to International Standards Organization (ISO) compliant card.	Complexity of establishing RCSC and associated POS network requires a formal requirements management process.	Major institutional issues in having to coordinate compatible system deployment among 16 regional transit agencies.	VERY HIGH	
Develop new control software including integration of legacy and planned ITS field equipment for the MTA B&T ATM IDEAS system in NY	Category 4	FMS	Very Complex	Advanced Traffic Management Incident Detect / Evaluate / Act System (ATM IDEAS) involves new development, COTS software and hardware, and legacy software integration.	Includes construction, communications, software development and deployment, legacy system expansion, ITS field equipment deployment, AVL/GPS, ETC, operations and maintenance. Multi-phase implementation.	Includes interfaces to several legacy systems such as analog CCTV camera system, HAR, radio system. External interfaces include TRANSCOM and E-Zpass.	Technology evolution a major issue to contend with. Standards being used to extent possible such as DMS NTCIP center-to-field standards.	Complexity of implementing ATM IDEAS requires a formal requirements management process.	Major institutional issues in having to coordinate ATM IDEAS internfally (linking together eleven small operations centers together with a new Centeral Operations and Control Center. Also externally with numerous operating agencies/entities in region.	VERY HIGH	

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Capital Wireless Integrated Network (CapWIN) Project	**Category 4**	PS/FMS	Very Complex	CapWIN involves new software development and implementation of COTS software and hardware.	Includes development of secure web-based software for mobile field users and center users. Includes implementation of network operations center housing all gateway and messaging switching hardware. Software functionality delivered in phases.	Includes interfaces to existing law enforcment databases and transportation systems.	Technology evolution a major issue to contend with. Private wireless services used by CapWIN users continues to evolve impacting speed of software client functions. Justice and transportation standards development efforts impact design of external agency interfaces.	Project complexity, new software development, and evolving requirements necessitates formal requirements management process.	Major instutional issues in coordinatiig a system linking senstive law enforcement databases, and 40+ public safety and transportation agencies in Metro DC region.	VERY HIGH	

[1]Aurora is an international program of collaborative research, development, and deployment in the field of RWIS involving U.S., Canadian, and European agencies.

FMS = Freeway Management System
TMS = Transit Management System
ETC = Electronic Toll Collection
TIS = Traveler Information System
IMS = Incident Management System
AMS = Arterial Management System
O&M = Operations & Maintenance
EFPS = Electronic Fare Payment System
PS/EM = Public Safety / Emergency Management System
CVO/CVISN = Commercial Vehcile Operations / Commercial Vehicle Information Network
WS = Weather System
RTM = Rural Traffic Management
RTIS = Rural Traveler Information
RTranM = Rural Transit Mobility