WHITE PAPER
DESIGN AND DEPLOYMENT ALTERNATIVES ATMS AND ATIS COMPONENTS OF IVHS

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PURPOSE

This paper has been prepared for the Federal Highway Administration under Contract DTFH61-92-00284 and is part of a series of papers being prepared under the title of "Ways to Improve Traditional Opportunities for IVHS Deployment". The paper addresses the specific issue of alternative procedures to be considered for the deployment of the time critical Advanced Traffic Management System (ATMS) and Advanced Traveller Information System (ATIS) components of IVHS. Further, the ATIS component is restricted to the field infrastructure and does not include the in-vehicle component. The alternatives considered are defined as "Program Management" and "Design/Build". These approaches are compared to the more traditional "Engineer/Contractor" approach.

BACKGROUND

The IVHS program has received unprecedented support during the last three years culminating in the Intermodal Surface Transportation Efficiency Act (ISTEA). IVHS developed out of a growing awareness that demand for transportation mobility was rapidly outstripping the nation's ability to supply transportation facilities. This was coupled with the strong consensus among professionals in the field that technology could be better applied to assist in meeting the demand for mobility. An ad hoc group, called Mobility 2000, was formed to develop the potential IVHS program and to generate support for the program concepts.

Mobility 2000 was a loose confederation of representatives of government agencies, private manufacturing and engineering companies, and the university community. The group was bound together by a common belief that IVHS offered opportunities to improve mobility and that the time was right to develop and deploy the technologies. Mobility 2000 successfully defined an IVHS program concept and became the foundation for a more formal association, MIS America. The U.S. Department of Transportation (with FHWA in the lead) moved the concept into a potential program. Congress reacted with enthusiasm and pushed an even more aggressive program, elements of which are now contained in the ISTEA.

A major challenge now rests with the transportation community, it must deliver on the promises made. Action is required at all levels of government, the private sector must be responsive to the needs, and the universities must provide the academic support demanded by the technology driven program. Congress, and the public, expects to see benefits from IVHS within a short time frame of perhaps five years and certainly no longer than ten years.

A major element of the IVHS initiative is the ATMS component and the public infrastructure needed to support ATIS. Advanced traffic management, including computer based traffic signal systems, comprehensive freeway surveillance and control systems, and integrated corridor systems, provide the backbone of IVHS. These region-wide systems provide the surveillance information required to know real time traffic conditions; provide the motorist information and control elements needed to optimize travel flow: provide the communications network needed to bring the information to points where it can be fused to support meaningful decision making: provide a focal point for distributing traveller information to impact mode, route, and time of travel decisions at trip origin or enroute; and support incident management.

As the surveillance and basic communications infrastructure are implemented and travel information fused into a comprehensive database, ATMS can provide the information critical to the ATIS component. Although elements of ATIS can proceed independently, it is likely that ATIS will not reach its full potential unless the ATMS information base is in place. (Note, there is potential for the ATIS to provide its own data source through the use of vehicles as probes however, this does not provide the link to control decisions.)

Mobility 2000 developed an estimate indicating that the ATMS element would require approximately $18 Billion current dollars) to deploy to the level needed to reach its potential and to support a significant penetration of the more comprehensive ATIS systems. The Draft Strategic Plan being prepared for the U.S. DOT envisions a parallel scale of program, with a somewhat slower implementation timeline than originally proposed by Mobility 2000. The program remains, however, but in orders of magnitude greater in scale than investments in ATMS have been in recent years.

Current directions indicate that responsibility for deployment will rest primarily with the public sector, with the private sector performing significant portions of the actual work. Public agencies have traditionally implemented ATMS projects in much the same way as they have other infrastructure projects. A design is prepared, either in-house or by a consultant, and the project is advertised and awarded to the lowest "qualified" bidder. (This approach is often referred to as "engineer/contractor".) In most cases, this has resulted in construction by an electrical contractor, with the technology elements procured from lowest cost suppliers or system providers. This approach has not had a good history of achieving the desired product.

It is the author's opinion that the classic engineer/contractor approach will not achieve the goals of the IVHS program in a timely manner. Also, it is believed that technical problems will continue to plague the process where the prime contractor is not directly familiar with the technologies involved. To set the stage of reviewing alternatives, the basic deployment activities are first presented. This is followed by a review of the alternatives and an assessment of their advantages and disadvantages, including institutional concerns. Brief scenarios are then presented to illustrate the deployment alternatives.

DEPLOYMENT ACTIVITIES

An aggressive deployment program for ATMS requires relatively rapid design and implementation of technologically advance electronic systems. The projects generally include: a traffic control center; hardware and software at a traffic operations center; installation of a communications network throughout the region; installation of all field devices for the control and traveller information elements of the system; integration of the field and central systems; and providing documentation and training to support the on-going operations and maintenance of the system. Typical of the basic activities to be completed are the following.

1. Preliminary Design: Feasibility studies generally develop the ATMS system to the concept level and this serves as the basis for estimating costs and program scope and securing project approval and funding. The concept level does not, however, provide sufficient detail to allow final design of the system. The concepts must be translated into specific system requirements, including location of field devices and final determination of system functions.

The preliminary design activity covers the work required to develop system details for the ATMS system to the point where final design can proceed. A comprehensive preliminary design insures that subsequent phases of work result in compatible system elements. The preliminary design also refines the deployment scheduIe and program costs. The design also identifies the systems and agencies which must be brought together technically and institutionally as part of the deployment process.

2. Final Design: The work in this activity is to prepare the plans, specifications, and estimates required to bid those portions of the system which are to be implemented by various contractors. (As a note, the grouping of system elements into bid packages is directly dependent on the deployment method and this is discussed later.)

Final design is normally completed in stages or sections as identified in the Plan. Given that ATMS technology is changing rapidly, it is expected that each design phase will result in some changes to the specific equipment to be provided but that backward and forward compatibility will be required as part of the design. This requires the deployment process to be sufficiently flexible to allow for the technology changes while insuring system compatibility.

3. Advertise and Award: This activity covers the work needed to advertise and award the contracts for actual deployment of field elements of the system and is generally performed by the public agency. In its simplest form, this may require letting several major construction contracts covering the identified

construction phases of the system. With ATMS, however, it is expected that significant pre-qualification may be required and that technical submittals may need to be evaluated prior to accepting bids.

It is also possible that the work phases will be further segmented, either geographically. or functionally, to allow more competitive bidding or bidding by contractors in specialty technical areas. Depending on contract breakdown, the advertise and award activity, then, may become a significant work task.

4. Construction: Deployment of the field devices for the ATMS will involve major construction contracts, especially for elements such as communications and detection. The majority of the field work is expected to be completed by contractors selected under the advertise and award activity. The majority of the ATMS volume generally falls under the electrical contractor category. Given the type of field work and local contracting conditions, construction staging and bid packaging becomes a major issue. Given almost any deployment alternative, the majority of field work will reflect some form of "low bid" process.

5. Construction Inspection and Technical Services: These activities cover the work needed to insure that construction is completed in accordance with bid documents and questions which arise are resolved. Much of the actual construction is standard work (such as trenching, conduit installation, installation of foundations, installation of detectors, etc.) and falls within the expertise of construction inspectors. Other elements, such as review of technical submittals and the resolution of technical questions will require special technical expertise. The construction services, then, involves standard construction management and the specialty work needed to insure conformance to bid documents.

6. Testing and Acceptance: This activity is technically a part of the construction inspection work but is separated to highlight its importance in an ATMS program. The work is to fully test the system elements and the entire system covered by a given contract. The testing begins with equipment at the manufacturers site and ends with the tests of the systems in-place. System elements are then accepted and the integration process is initiated.

7. System Integration: Each of the construction phases and contracts will have to be integrated into applicable "systems" and then into an operating system. The integration work involves the connection of system elements into the operating hardware and software at the traffic operations center, preparation and installation of operating plans and databases, and modification to any previously installed equipment and software as may be required. The integration is a continuing activity throughout the life of a program and covers all phases of deployment. The integration activity may include interties with several other systems, such as transit information centers, emergency dispatch centers, and the media. Operating plan and database development is a much more significant activity than generally recognized.

8. Operations Support: As system elements become operational, it is essential for them to fit into any on-going operations and maintenance. The work in this activity is to provide the system documentation (including as-builts and manuals), training of operations and maintenance staff responsible for on-going operation, and technical support as may be required to compliment the full time staff assigned to the ATMS program. The specialty support may involve continuing operations planning, database development, software maintenance, or specialty skills reIated to the hardware which is deployed.

ALTERNATIVE DEPLOYMENT APPROACHES

There are three basic approaches which may be considered for deploying the ATMS system: engineer/contractor or turnkey bid, program manager, or design/build The following is a brief discussion of the alternatives.

1. Engineer/Contractor: This procurement approach has traditionally been used by most transportation agencies. Typically, an engineer prepares a single set of contract documents (PS&E) for a specific phase of the proposed system, For an ATMS project, a specialty design consultant is generally used, however, some public agencies have in-house capabilities. The contract documents are then advertised, bids are received from contractors, and the project is awarded to the lowest responsive bidder. The winning contractor is responsible for providing a complete and fully operational system, including furnishing and installing all hardware and any required software, system integration efforts, training and documentation,

and, in some instances, the development and implementation of operations plans. The consulting engineer often continues his/her activities during system installation by monitoring the contractor's progress, reviewing contractor submissions, participating in the system testing, providing interpretations of the plans and specifications, and developing system database and operations plans if not performed by the contractor. The engineer may also provide training.

With the engineer/contractor approach, there is generally only one contract to prepare and administer per construction phase. However, no single prime 'contractor possesses the necessary experience and qualifications to perform all of the work included in the typical ATMS turnkey systems contract. For example, electrical contractors may not have electronics engineers or programmers on staff for developing and integrating technology elements and software. Similarly, a systems firm is not capable of installing conduit and pulling cable. The prime contractor for a turnkey systems project must, therefore, subcontract a significant portion of the work, and the subcontractors may in-turn subcontract portions of their work.

The prime contractor is contractually responsible for the work and the actions of the subcontractors and equipment suppliers. How well the prime (i.e., responsible entity) coordinates and manages its subcontractors is therefore critical to the project's success. Administering multiple layers of subcontractors and suppliers is difficult even under the best of circumstances. It requires good human relations, technical expertise, and familiarity with the type of work being performed by the subcontractors. An ATMS project, particularly one involving a state-of-the-art ATMS system, encompasses a wide range of technologies, equipment, construction techniques, and related services. The prime contractor may not have sufficient knowledge of some of these elements to select appropriate or qualified subcontractors, and then to effectively administer and control their actions. The prime contractor will depend principally on bid price for selecting subcontractors and will place specification adherence responsibility on the subcontractor and in-turn, the administering agency.

Another important consideration with a turnkey project is what type of firm will be the prime contractor. Often, the majority of the project's dollar value involves field construction and electrical work, in which case it may be best to have an electrical contractor as prime. However, with this arrangement, the administering agency may not be able to deal directly with the electronics and systems subcontractors — the firms hired by the prime contractor to develop the equipment, related software, and to integrate the system. Interaction between the agency and the organizations developing the technology elements is very important for success.

In the engineer/contractor approach, the administering agency generally retains the primacy responsibility for ensuring conformance with bid documents and for testing and accepting system elements. The agency is also generally responsible for coordination between contractors working on various phases of the overall program. For most ATMS projects, this would involve various engineering firms performing final design as well as the construction contractors and suppliers.

The engineer/contractor approach most closely fits most public agency's procurement procedures. It is, therefore, the easiest to pursue and the one that requires the least institutional reorganization.

2. Program Management Approach: With this approach, a program manager becomes the responsible entity. The "program manager" may be a specially staffed and equipped office of the public agency or, more likely, a technical consulting firm. The activities of the program manager typically include preliminary design and program definition, preparation of standard bid documents, preparation of final bid documents or supervision of others preparing final design, construction engineering and inspection or supervision of others performing these services, development of any required software, procurement of software-dependent hardware, system integration, preparation of operations plans, and training and documentation. Overall program management and quality control is also provided. The contract between the agency and the program manager is expected to be a negotiated agreement for engineering services similar to design contracts.

Instead of a single tumkey contract, several contracts for the various subsystems are prepared. Examples of these separate subsystem contracts include the various construction phases; construction of the traffic operations center; procurement of communications hardware; procurement of computer and display hardware; installation of sign support structures; and field electrical work (e.g.. new ramp controllers, loops, communications cable, signal displays, signs, etc.). The agency's normal procurement processes are generally used to procure the individual subsystems and services however the program manager could also serve as a contracting entity (especially for the specialty hardware items). The program manager may administer these contracts and is responsible for integrating the various subsystems into an operating system. The program manager also controls technical specifications and standards throughout the construction phases even where design work is done by others.

An inherent feature of the program management approach is that the overall system design, any required software development, and system integration and testing activities are all controlled by a single entity — the program manager. This provides continuity throughout the process as well as a single source of responsibility and accountability. This "responsible entity" cannot blame its problems on the overall designer as they are one-in-the-same. It is essential that the program manager be qualified to perform the various program management activities, and that it have the proper facilities for system design, development, integration, testing, training, and operational support.

Another characteristic of the program management approach is that the engineering agreement between the owner and the program manager is generally negotiated. This allows both parties to jointly determine the scope of work, define their respective duties and responsibilities, develop a realistic estimate of the corresponding costs, and to fully understand what is required from the ATMS system before the work actually commences. Experience has also shown that these engineering agreements for program management offer the owner more flexibility over time as compared to the more rigid conditions of low bid or tumkey contracts.

When multiple contracts are used, as they generally are with the program management approach, it is critical that all necessary components be included in the various contracts. For example, if one contract covets installation of variable message signs and another contract addresses the sign support structures, then one of these contracts must also include power service conduit. Putting a particular component in the wrong contract can also cause problems. For instance, the procurement of complex communications equipment and other high-technology items probably should not be included in a field construction contract. Similarly, the supplier of sophisticated systems equipment is not best suited to install foundations or conduit.

Proper sequencing and coordination of the various subsystem contracts is critically important during a major ATMS project. This project management and coordination activity is one of the major responsibilities of the program manager, and is a significant factor affecting project success.

The program management approach, also sometimes referred to as an extension of systems management, has been used for the successful implementation of several major ATMS projects. It was developed in response to problems in implementing traffic control systems under the engineer/contractor approach.

3. Design/Build Approach: In the design/build approach, a single responsible entity is selected to perform all work associated with the deployment of the ATMS system. The public agency's sole role is in monitoring the activity of the design/builder. The design/builder performs all design work, contracts and/or constructs system elements, commissions the system and turns it over to the operating agency.

In the United States, the de-sign/build approach has most often been applied to buildings and to Department of Defense procurements. One or more firms develop a conceptual plan for the building (such as a government center, a hospital, or a prison) or defense system and the concept is selected. The firm then carries the design through preliminary engineering or design, generally expressed as the "30% design level". Negotiations are then conducted for the final cost of construction. This may be done as a fixed amount or on the basis of unit prices for estimated quantities with payment on actual quantities. As a note, design/build is used extensively for transportation projects outside of the United States. There are no direct models for the ATMS application, although some projects are under consideration.

After the agreement is negotiated, the design/builder completes all aspects of the project in conformance with the preliminary design. Changes are generally negotiated similar to a turn-key contract.

A key attribute of the design/build approach is the complete transfer of responsibility to the design/builder. This generally allows the project to be completed more quickly in that procurement procedures can be streamlined and problems can be resolved quickly. Also, the design/builder is under significant incentive to complete all work quickly and turn the system over to the agency to reduce it's costs and risks. Assuming a qualified design/build team, all skills rest with the entity and closer coordination and cooperation can be provided.

The approach does place a burden of supervision on the agency to insure that quality is maintained in that the design/builder is now at full speed and is reluctant to change directions. This may offer some difficulty in coordinating technology changes. It also may force the agency into making decisions more quickly than they are comfortable with. The process is also the least well known in the ATMS industry and procedures are not well established.

REVIEW OF ALTERNATIVES

There are a large number of elements to be considered when selecting the best approach for implementing ATMS in a given region. The purpose of this section is to describe the primary attributes of the alternatives in light of selected key elements with the understanding that a more complete development of a recommended alternative will be requited as part of the overall deployment effort for a specific project. The key elements chosen for the review are: time to complete; risk (in meeting defined expectancies); total program costs or life cycle costs; the requirement for public agency personnel resources; the functional and technical adaptability of the system during and after deployment; and institutional compatibility. A discussion of the alternatives under these key elements is summarized below. A table listing key advantages and disadvantages of the three alternatives is provided as a summary to this section.

1. Time to Complete: The overall ATMS program of IVHS envisions a very aggressive implementation schedule, with significant complete deployment in the next six years and a ramping up again for the next ten years. Major projects will have to be completed in 3-5 years. These same scale projects might normally require 7-10 years to complete given phased deployment.

To meet the scheduled level of implementation, the deployment process must be as streamlined as possible and avoid bureaucratic tie ups where possible. To do this requires the entire program to be placed on a priority schedule and receive the staff and capital resources required to make the system work. Design, review and approval, advertise-award, construction, and integration and testing must all be on a fast track.

The design/build alternative offers the greatest opportunity for rapid deployment. In this alternative, the design/builder takes on all primary contract management and procurement responsibilities and can use standard "private sector" procedures for quickly administering the overall program. Each of the phases of construction can be broken down as required and assigned to subcontractors based on real time evaluation of resources and needs. Staging can be altered quickly as needed to complete the overall program. Contracting incentives, scheduled procurements, and short award cycles can all be used to accelerate the program.

The *program* management alternative is also a method for expediting schedule, however it operates within greater constraints than design/build. Specifically, the approach generally uses a part of the public agency contract advertise and award system and contract administration procedures, and this restricts the degree of freedom Schedules can be adjusted somewhat in real-time to reflect need since program elements are further segmented from that envisioned under the engineer/contractor approach. Time critical elements can proceed as a priority. Also, the use of a program manager (likely a private consulting team) allows resources to be assembled more quickly to respond to schedule demands. The work load can be uneven and still beaccommodated. Since many of the administrative tasks are conducted by the program manager, this work can also be expedited as required.

The alternative that presents the greatest time to complete is the classic engineer/contractor alternative. This places the requirement that major segments of work be completely designed and reviewed and then bid. The time critical elements cannot be accelerated as the process requires for the project to proceed as a unit. Further, the consultant procurement cycle often must be completed for each phase of the design work using standard agency procedures. To complete the program in a timely fashion, the public agency would have to establish a "program management office" similar to that envisioned above and develop special procedures for handling the project.

2. Risk: There is always a degree of risk associated with implementing a technology based system. The risk may be characterized by the degree to which the final system meets the expectancies or requirements of the end user and the time and cost risk. The majority of risk can be mitigated in the design process and by the techniques used to manage deployment contracts. Each of the alternatives, however, offers greater opportunities or challenges for reducing this risk.

The program management approach offers promise for insuring that the final system meets user expectations. The primary reason for this is the use of a technically qualified team from preliminary engineering through training. This insures continuity in understanding the project and in quality control to meet the requirements which are defined This technical continuity allows the various phases of work. to be managed by a single control point. Changes which are needed to reflect technology changes are placed into subsequent design activities with full understanding of their need for backward and forward compatibility.

The design/build also offers promise for satisfaction of this criterion. Continuity is provided and changes can be reflected in subsequent designs. The alternative offers some difficulties in that the emphasis of the design/builder is on deployment once a level of design has been completed (say 30%) and prices have been negotiated. Changes are considered similar to a change in scope for a general contractor and can cause negotiation problems when trying to include them in on-going work. The design/builder must also be primarily concerned with the construction activities as this represents the bulk of work. This may reduce the concern for the design related efforts.

The engineer/contractor offers the least promise in this criterion. Difficulties arise from the lack of continuity, the likely involvement of a number of entities that are responsible for design, and the inherent inflexibility of large construction contracts. The likely orientation of the contractor toward electrical contracting places the technology elements at a lower level of priority and these may be assigned to a leas than capable subcontractor. Once a design base is established in the preliminary design phase, it becomes difficult to make changes that are compatible with other system elements. The time between design and deploy also places added risk because technology is changing so rapidly. A design may be obsolete before it is used.

3. Total Program Costs: This criterion covers all aspects of costs for deploying the system, including design, administration, construction, and initial "commissioning" of the system. It is a difficult criterion to assess because each of the alternatives result in potential cost increases or decreases in differing components of the total program. For purposes of initial discussion of alternatives, they are estimated to be approximately equal in total cost, but with the differences noted below.

In the engineer/contractor approach it is likely that the basic design work and construction would be done at a lower cost that the other alternatives. This reflects the fact that major elements would be bid to a single lowest cost contractor who would have solicited lowest costs from suppliers and subcontractors. Design contracts may have individually considered cost in the award. The cost risk in this alternative is in three primary areas. First, the contract sizes will be so large that there will be a limited number of potential bidders. These bidders will be subcontracting significant elements of the work and will place a burden or fee on the subcontracted elements. It is possible that the total bid price will be higher than if a series of smaller and/or specialty contracts are bid. A larger segment of the overall costs are reported by the public agency. These costs may appear low because actual overhead is often not reported or accounted for directly by public agencies.

Contract change orders offer the second area of cost risk, The single large wntracts designed by a series of engineers have sometimes resulted in significant cost overruns as efforts are made to make the systems compatible. There are several examples where costs increased 50% due to change orders issued after the bids were received. A third area of cost concern is in administering the contracts and in integrating the elements as they are constructed. The potential for several contractors to have integration responsibilities adds to the difficulty in insuring coordination with the on-going operation of an ATMS system.

In the program management approach, significant costs are incurred with the program manager. The task of administering and managing the overall program and for selected design activities are directly reported and are burdened with overhead and fee. Integration, training, technical assistance, software as required, and other "construction" costs are also directly attributed to the program manager costs. The potential cost savings are in how the bid packages are developed and bid By segmenting the packages into appropriate sizes and functional areas it is often possible to reduce individual bid costs and to avoid prime contractor burdening. Costs for integration may also be lower with a single cognizant technical entity where a major prime contractor would associate "risk" with the work and charge accordingly.

The design/build approach may offer an opportunity to reduce overall costs by concentrating the responsibility for the project in a single point and allowing procurement and size efficiencies to be effective. The area of cost risk for this alternative is in accepting design changes which may be required because of the changes in ATMS technology. There is also some cost risk associated with the interest of the designer in developing lowest technical risk and maximum participation by his/her forces and/or equipment. There is also some potential for using overly sophisticated equipment to increase the contract value.

4. Requirements for Public Agency Personnel Resources: The implementation of a major ATMS program will place added demands on the technical resources of the public agency regardless of the approach taken. Resources will be required to administer, in some form, the major increase in the design and deployment of ATMS technology. The scale of envisioned programs is outside that of the normal operation of most public agencies and significant and commitments will be required. The requirements do differ, however, with the approaches and this is discussed below.

The engineer/contractor approach places the greatest demands on local agencies' personnel in that the overall program management and responsibility will fall within their normal procedures. All consultant engineer selection, contract monitoring, and bidding would follow the current practices of the agency. Technical and administrative staff would have to be assigned to the ATMS program for its duration, with emphasis on providing the technical resources needed to insure continuity and quality control. It is likely to prove difficult to assemble the resources in a timely manner and to attract the specialty skills which are required.

The program management approach should significantly reduce the demand on public agency staff resources. In essence, the program manager serves as an extension of the agency staff to provide the needed technical and administrative support for the project in *addition to performing technical work* elements. The primary agency role would be to monitor and administer the program manager's contract and to provide sufficient technical staff to participate in decision making and to provide operating continuity as the ATMS system is deployed. This alternative may also be considered to require a larger commitment, depending on the level of use of the public agency advertise and award procedures and construction inspection and administration.

The design/build approach requires a moderate commitment of public agency staff to the program. As. with program management, the design/builder will take on the majority of the technical and administrative work for the project. As well, the design/builder will reduce the agency burden for contract award. The reason the approach is considered moderate is the need for monitoring of the work of the design/builder after the preliminary design is completed. At this point, the motivation of the design/builder is to expeditiously complete the work at an acceptable cost. Monitoring is required to insure that the final product meets the identified requirements and that quality control is maintained. This approach could also prove to be very low in demand for staff resources if the design/builder proves to be very good in monitoring his/her own work. Also, a technical consultant could be retained by the public agency to monitor the design/builder.

5. Functional/Technical Adaptability Most ATMS systems will be installed over a several year period. The preliminary design and subsequent final designs should reflect technological advances as appropriate. This dictates a process which will accommodate change while keeping deployment on course.

The program management approach appears to offer significant promise under this criterion. The approach itself is inherently flexible, leading to the ability to accommodate change. The change can be controlled and integrated into the overall program through the technical and administrative staff of the program manager. The continuity with the program and the centralized technical decision making insures forward and backward compatibility. As an extension of the public agency staff, the program manager has a vested interest in the overall program rather than a segment or project.

The engineer/contractor approach may offer significant difficulty in meeting this criterion. Assuming phased implementation, the use of individual designers makes it more difficult to control changes which occur and the tendency is to minimize any change from the base line which is established in the preliminary design. Also, the level of technical capability of the various designers will vary, again requiring the use of relatively rigid standards. As the project moves into a large construction project, likely led by an electrical contractor, technology changes are also difficult to incorporate. Given the integration responsibility of the contractor, that organization will be reluctant to make changes to the technology components.

The design/build approach may offer difficulty in meeting this criterion, depending on the method of contracting for implementation once preliminary design is completed The positive element of the design/builder is the single point of control and coordination which could provide the needed continuity and coordination to incorporate change. The approach may be effective if procedures for compensating for change can be developed as part of the process of contracting for the design/builder, or it may prove difficult if the contract procedures parallel that of the engineer/contractor.

<u>6. Institutional Compatibility:</u> Given that ATMS systems are likely to fall into the domain of the public sector, consideration must be given to how the alternatives might be accepted. Also, as a complicating factor, it is expected that the majority of the projects will involve several agencies. This reflects the fact that the systems are expected to cover large geographic areas (or at least be coordinated across large areas) and both surface streets and freeways. The traditional interests of the states has been in systems on the freeways while cities have had the responsibility for systems on surface streets. There are significant exceptions to this, but the general case is true.

The design/contractor approach most closely fits the institutional pattern for deploying large infrastructure projects. Both state and local agencies are familiar with the approach and are comfortable with using "low bid" procedures to insure fair competition for projects. The use of relatively rigid specifications, routine advertising and award cycles, and fixed contract terms fits well with the normal construction project and has been used successfully for federal aid projects for years. Specific procedures for resolving claims or other disputes have been developed and are well understood. In some areas, the public agency has held that this process is the only "legal" approach that they may take. In other cases, it is simply difficult to change procedures that have been established for a long time.

The program management approach (generally under the name systems management) has also been used by a large number of agencies for implementing advanced traffic management systems. Program management has also been used by several agencies that were embarking on major freeway construction programs, such as those financed by sales tax increases in Arizona and in California. Program management was used for the reasons identified at the beginning of this paper, major deployment was scheduled and the public sector could not effectively gear up, then down, to handle the loading. Program management for ATMS was developed specifically in response to problems with the engineer/contractor approach in early implementations of computer based traffic control systems. Most agencies appear comfortable with the approach and have determined that the work can be awarded on the basis of technical and qualification based selection procedures, with or without early consideration of costs. The approach has been rejected by some agencies, especially at the state level, but appears generally compatible with existing institutional constraints.

The design/build approach offers the greatest challenge to existing procedures. Although allowed under certain FHWA procedures, the approach has not been broadly accepted in transportation projects or, specifically for ATMS projects. The primary difficulty appears to be in the perception that "lowest cost" and competitive procurement cannot be guaranteed. Agencies feel at risk for being criticized for favoritism or for unwise use of public funds. These concerns are real and must be considered. In some agencies, the legal or procurement offices have ruled that the agency guidelines specifically prohibit design/build contracting. At the same time, several government agencies have used design/build procedures for developing technologically advanced systems (the DOD and NASA) and some public building has been provided in this manner. The challenge, under this alternative, is to develop guidelines under which the process may be used and to have successful models from advanced agencies that others may follow.

Both the program management and design/build alternatives offer an unusual potential benefit with regard to the issue of several agencies being involved in many of the projects. As an "independent" entity, agencies may be more trustful of the private party than they are of another agency with whom they have had a history of "turf" battles. Oddly, the private party can become the meddler/mediator that assists in resolving complex institutional issues. The project itself can become the focus of the group, rather than the specific roles of the individual agencies. By participating in all elements as a group, none is giving up any direct responsibility to the other. A team effort can result if this is carefully handled. This is not meant to imply that a public agency cannot serve this role, it is simply meant that an outside entity may . fiid the role easier.

SUMMARY OF ATTRIBUTES OF ALTERNATIVES

Exhibits 1 through 3 show the basic advantages and disadvantages of the three basic alternatives. Each of the alternatives have both advantages and disadvantages, so the key to determining the best approach for a given program or project is to establish the relative value of the advantages and disadvantages. The engineer/contractor alternative alone is not likely to result in the deployment of ATMS at the scale and in the time frame envisioned as needed to fulfill the promise of the IVHS program. The primary reasons for this judgement are:

- **The process is too burdened in bureaucratic procedures to expeditiously &ploy technology based projects.**

- **Many of the steps in the process are sequential, building delays into the overall time schedule.**

Exhibit 1. Attributes of Engineer/Contractor Approach

ADVANTAGES

- Matches current practice, fits institutional model
- "Low bid" guarantee for implementation stage
- Single construction contract to monitor

DISADVANTAGES

- Longer overall time to deploy
- Aging of specifications during design/ award cycle
- May result in "wrong" type of contractor
- Difficult to make changes
- Requires substantial commitment of public agency staff

Exhibit 2. Attributes of Program Management Approach

ADVANTAGES

- Defined technical responsibility
- Qualification based provider of technical services elements
- Easier to modify during program
- May reduce costs through effective procurement
- May be faster to deploy, depending on procurement procedures
- Good contract breakdown to match project elements
- Reduces **need** for public agency staff (selective involvement)
- Somewhat consistent with current institutional practices

DISADVANTAGES

- May require significant time depending on approval and procurement procedures
- Places some elements in a "cost plus" environment verses low bid
- Significant agency dependence on the qualifications of the program manager
- May be difficult under some institutional constraints

Exhibit 3. Attributes of Design/Build Approach

ADVANTAGES

- Substantial opportunity for timely delivery of large scale ATMS projects
- Reduced demands on public agency staff
- Technically qualified prime contractor with single point responsibility
- Has potential to reduce costs through efficient procurement
- May provide technology advantages and may be easier to adapt than engineer/contractor approach

DISADVANTAGES

- Difficult to implement under certain institutional constraints
- Difficult to assess in terms of cost (may require competing designs in early stages)
- May be difficult to modify once design is set
- Significant agency dependence on design/build contractor
- May require second party monitoring or significant agency monitoring

- Low bid contracting for all elements makes it difficult to consider technical quality and life cycle costs.
- The lack of flexibility during the various stages results in documents becoming obsolete as well as difficulty in adjusting to changes in technology.
- The likely contractors may not be the best suited for the critical technology elements, upon which system success depends.

It is mast likely to succeed in areas where the process is well established with specific experience in the ATMS field, where a strong technical staff has been developed in-house, where overall time allows for the programmatic approach, and where agency relationships are well organized.

The program management approach appears to offer the broadest base for application in the near term. The bases for this judgement are:

- It has been used in a somewhat similar form (systems management) for the successful implementation of major ATMS systems.
- The process fits generally into the procurement practices of most public agencies.
- Many of the major cost elements are directly bid and awarded to the lowest cost contractor or supplier.
- The contracting process allows significant flexibility in resolving technical problems and adjusting to technology changes.
- The process minimizes the need for additional technical staff to be developed within the public agency, but offers the “feel” of an extension of the agency staff.

There are concerns, however, that the process places too much of the program into the hands of a private firm and that too much of the work is completed under a negotiated services agreement. Also, the process can result in significant delays if contract award procedures are not streamlined or if lengthy review are required.

The design/build approach also appears to be a viable alternative that should be used in implementing ATMS systems. The primary reasons for this opinion are:

- Design/build will allow very large deployment projects to proceed quickly from concept to operational status. This key element of design/build offers the greatest opportunity to meet the IVHS promises that have been made.

- The approach does not require a major build-up in public agency staff.

- Technology based firms can be selected on the basis of merit and competitive (not necessarily lowest) cost, rather than having the program driven by construction based firms.

At the same time, serious consideration must be given to the conflict between this approach and standard institutional constraints. The approach must be demonstrated as successful so that models of application can be developed. In some cases, enabling legislation will be required at the various levels of government to permit use of design/build. This will obviously cause a significant delay in using the approach in agencies where a real or perceived legal problem exists. FHWA will be a key player in this issue and procedures need to be developed in concert with potential design/builders and the public agencies that have an interest in the approach. As a note, at least one state is currently considering design/build for an ATMS project.

DEPLOYMENT STEPS

The following are brief descriptions of the steps that may be taken to use the program management or design/build approaches. (The engineer/contractor approach is well established and the procedures are well documented.)

PROGRAM MANAGEMENT The following are representative of the steps that may be taken when using the program management approach. The steps assume that the lead agency is a large public sector agency and that the concept level definition of the ATMS and ATIS systems have been defined.

- Define level of participation by the agency, that is, what part of the overall work will be accomplished by the agency, the program manager, and any other subordinate designers.
- Prepare request for proposal and solicit proposals.
- Evaluate proposals and select program manager.
- Negotiate scope of work, contract terms, and costs with program manager (likely a cost plus fixed fee agreement).
- Program manager prepares preliminary design, project report, and implementation plan for overall program. Implementation plan defines contract stages, types of procurement for various elements of the system, and detailed responsibilities for all remaining work tasks.
- After approval of plan, prepare detailed design guides, final design of initial stages, specifications and bid documents, and support advertise/award cycles as appropriate.
- Develop work plans for other design packages (that may be prepared by the program manager or by subordinate subcontractors) and proceed through design stages.
- Program manager provides technical assistance for all contracts and either program manager or agency provides construction inspection and contract administration.
- Program manager prepares system software, performs tests, performs system integration and start-up and provides (or provides technical support) for database and operations plan development.
- Cycle is repeated as needed for various construction stages with program manager taking lead role in maintaining bid documents to current technology levels.

As noted, the primary role of the public agency is to administer the program manager contract and to provide any desired level of services in general contract advertise/award, inspection and administration, and operations plan development.

DESIGN/BUILD: The design/build approach raises several issues which are not clearly defined. The following are "typical" of the steps which might be taken, based on the judgement of the author. There are a number of major assumptions that must be made to permit a simplified description. For purposes of this paper, the following assumptions have been made: 1.) the design/builder will compete for the basic project on the basis of qualifications and technical proposal; 2.) costs will be considered as part of the evaluation process but will not dominate the decision, that is, reasonableness checks are made vis a vis competing proposal; 3.) the initial scope of work and contract will cover a preliminary design stage similar to that envisioned for the program manager (say design to the 10 - 25% level): 4.) after approval of the preliminary design, a fixed price or unit price contract will be negotiated to complete the project — at this point prices become fixed and the project proceeds somewhat as a general contract would. It is recognized that competition may be required by some agencies for the final implementation. In this case two or three teams would be paid to develop competing preliminary designs and a final firm would be selected on the basis of the quality of the design and a form of evaluated cost.

- Define overall program goals, objectives, and conceptual &sign of the ATMS (done by the agency or by a consultant).

- Define work activities to be done by the design/builder and by the agency and any technical consultant that may assist the agency in supervising the design/builder.

- Develop request for proposal, solicit and receive proposals from firms or teams. Given the specialty nature of ATMS work, it is likely that a pre-qualification stage should precede the RFP stage to limit the submittals to firms or groups of firms that are well qualified to perform the work.

- Select one or more teams to develop the preliminary design to a point where items of work and quantities can be estimated at, say, the plus or minus 5% level.

- Upon selection/approval (depending on whether one or more firms were used in the initial stage) move to the negotiated procurement of the final system. As noted earlier, the public agency may monitor the work of the design/builder with their own staff or use a technical consultant to assist in the monitoring activity. (DOD contracting offices often use a team of experts as a technical review panel to assist the government)

- The design/builder then completes the final design and implements the entire system. Some of the work will be done with the design/builders own forces and other elements may be performed by subcontractors selected and administered by the design/builder. The design/builder is completely responsible for the successful implementation of the project for the agreed costs and any negotiated changes.

SUMMARY

There are several ways which can be used to implement major ATMS elements of the IVHS program. It is the authors opinion that three methods described in the paper all offer potential and that all will be used. It is also the opinion of the author that none of the three, in isolation, are likely to meet the expectations of the IVHS program. The engineer/contractor approach is to slow and cumbersome and may not adequately treat technology based projects, and neither program management or design/build will be accepted by all public agencies, with the design/build likely to meet the strongest resistance by some agencies.