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ABSTRACT

This paper describes the results of an assessment of benefits from an ITS architecture, based on the National ITS Architecture Development program. Benefits of the architecture, in this paper, include those typically attributed to systems engineering and integration. Because the national architecture has addressed ITS as a whole, the product can be seen to be a comprehensive treatment of ITS-related data flows and functional requirements. The architecture provides a common framework so that, in planning and implementing systems, state and local agencies can be assured that ITS products and services are compatible and inter-operable with other ITS products and services. More directly, three beneficial features of the national architecture can be identified: 1) a framework for system integration; 2) common data and functions; and, 3) open interface standards. These architecture characteristics are likely to result in lower system costs and higher benefits for ITS users as well as product suppliers. First, the national architecture provides a comprehensive specification of ITS functions, interfaces and data flows. This level of specification means that system integrators can leverage the architecture to create system designs in which products and services are inherently compatible. Second, the national architecture presents a framework by which system designers may leverage common data and functions to achieve various system goals. Systems can be designed efficiently, avoiding redundancy. At the same time, each ITS technology may serve multiple functions, thereby allowing significant cost savings by sharing this common resource. Finally, the development of open interface standards, based on the architecture, has benefits in allowing products and services to be compatible across an architecture interface. Architecture-compatible system designs can leverage interface standards to reduce the ultimate cost of system purchase, operation, maintenance, upgrade and expansion. In these ways, the national architecture may provide significant benefits in the long run for ITS system designs and implementations.

INTRODUCTION

The National ITS Architecture Program

In 1993, the US Department of Transportation (USDOT) initiated a program to define and develop a national Intelligent Transportation Systems (ITS) architecture. This program consists of two phases. In the first phase, which ended in December 1994, four competing teams were selected to develop preliminary architectures. Phase II of the program, which began in February 1995, is a cooperative effort among teams headed by Loral Federal Systems and Rockwell International Corporation (the Architecture Development Team) to develop a single national architecture. This program will be completed in July 1996. Activities within the program include defining the details of the architecture, evaluating the long-term performance of the architecture, and developing a strategic plan for implementing the architecture (2).

The national ITS architecture defines a single framework that may effectively guide the development and implementation of ITS user services over the next 20 years. As defined by the USDOT (1), "a system architecture is the framework that describes how system components interact and work together to achieve total system goals. It describes the system operation, what each component of the system does and what information is exchanged among the components. A system architecture is different from a system design. Within the framework of an architecture, many different designs can be implemented."

Architecture Definition

At the heart of the national ITS architecture is a core set of functional requirements to provide 29 ITS user services. These functional requirements have led to a detailed specification of data flows and functions that must be performed to achieve this level of functionality. The architecture itself identifies subsystems where these functions are performed and the architecture flows necessary between those subsystems to ensure basic, or more advanced, functionality. Through this definition, the architecture presents a clear framework for integrating ITS functions and for connecting different ITS systems.

In addition, for evaluation purposes, the Architecture Development Team introduced the concept of *market packages* (2,3,4,5). These market packages represent a "deployable" package that is consistent with the architecture definition. Each market package defines a smaller set of functions, the required data flows into and out of those functions, and the assignment of those functions to a particular physical entity. The advantage of the market package concept, compared with using the architecture as a whole, is that it allows further analysis of likely implementation paths for ITS products and services.

As currently defined, the national architecture has several desired system characteristics: it provides comprehensive support for ITS services, inter-operability of components, open interfaces between systems, substantial flexibility in local ITS system design, and support for both the near-term and long-term evolution of ITS products and services. It is precisely these technical features that in turn suggest the specific benefits of the national ITS architecture. Previous research (3,4,5) has identified five critical factors that characterize the benefits of a national ITS architecture:

- **Social Acceptability**: Will the architecture be accepted by users and non-users?
- **Flexibility**: Will the architecture handle the many uncertainties of future ITS developments?
- **Guide-ability**: Can the implementation of the architecture be guided effectively by public policies?
- **Sustain-ability**: Can the architecture enhance the long-term viability and growth of ITS?
- **Ignite-ability**: Are there sufficient elements within the architecture to enhance deployment of early, high-benefit ITS products and services?

These factors capture the ability of the architecture to create an acceptable and, in the long term, useful framework for ITS system and component designs. In essence, the national architecture should provide a fundamental building block to assist the public sector, private sector and individual consumers in developing, designing, and implementing ITS products and services.

Outline

This paper describes our assessment of how the national ITS architecture supports these long-term goals, and, in turn, provides benefits for long-term ITS system implementations across the country. In describing the benefits of the national architecture, the primary motivation has been to address these benefits in the context of ITS systems integration. Because the national architecture represents a comprehensive treatment of ITS most broadly, systems integration lies at the very heart of the architecture development effort. The first section of this paper presents a broad overview of system integration and the nature of these benefits. Two salient aspects of system integration that are called out in the national ITS architecture program include: (1) synergy in data sharing, functional coordination, and common technologies; and, (2) recommendations for open interface standards. These two areas, developed in subsequent sections in this paper, provide a convenient framework for discussing more specific benefits from the national architecture. A final section offers some conclusions regarding the long-term value of the national architecture.

BENEFITS OF SYSTEM INTEGRATION

The fundamental nature of the national architecture is to provide a framework to incorporate the widest possible range of ITS services and the ways in which those services will interact in the future. In other words, the architecture is the most basic tool to integrate ITS systems into a common system to achieve the ultimate goals of ITS. For the purposes of our analysis, we have chosen to differentiate the concept of systems integration as it naturally occurs in two areas: *architecture definition* and specific *system design and implementation*. Ultimately, it is when local implementors design and implement their systems that systems integration occurs. However, the root benefits of system integration occur for two reasons: (1) effective definition of the system architecture, and (2) effective use of the architecture in creating the system design. These two areas are explored below.

Architecture Definition

The national ITS architecture has considered ITS in its broadest possible terms, across the full set of 29 user services. This means that all of the different services envisioned under ITS are considered simultaneously in the architecture definition. As a result, the architecture identifies not only functions and information flows for each user service, but also those that are shared across user services. In this way, the architecture development process ensures that common functions, data and information flows are identified. At the architecture level, this provides a high-level, top-down system engineering approach to system development.

At the level of the architecture, there are clear benefits to this systems engineering effort: functional coordination and facilitation of data sharing. First, the architecture has generated a comprehensive list of functions that must be performed to complete 29 user services. While no one area is likely to implement all 29 services, the architecture identifies functions that may support multiple services. In this way, the architecture allows a system designer to identify what level of functionality is desired, where those functions should be performed, and how each function supports other functions in an ITS system.

In addition, data sharing is facilitated when either common data are used in a broad range of ITS functions, or when suitable data transfer and interface requirements are defined. The national ITS architecture specifies a comprehensive data dictionary and has produced a set of suggested architecture flows on various subsystem interfaces for ITS. These products are intended to enhance the sharing of data and to support the development of open interface standards. As discussed in the fourth section, these data compatibility and interface standards provide considerable benefits for both ITS users and system vendors.

System Design and Implementation

More practically, those responsible for designing and implementing ITS systems must integrate multiple and diverse information technologies to enhance the transportation system. Such integration may provide significant benefits in the form of: (1) compatibility among system components; (2) data sharing among different components and jurisdictions; and, (3) synergy among common functions, data, and technologies. The ability to integrate advanced technology means that in the short run, the existing hardware, software, and data base packages needed for ITS can be compatible with new and emerging products. In addition, in the long run, technologies will be less expensive to procure and operate. Compatibility of technical systems, and the ability to use different technologies in an integrated fashion, allow the most cost-effective and efficient operation both of the technology and of the transportation system.

A national architecture allows the engineering contractor to select components from vendors that meet a common, nationally accepted system definition. Furthermore, the contracting organization can more easily and accurately specify the services and products for procurement. This ensures that the new technology will be compatible with existing technical systems. Specific benefits of system integration at the level of system design and integration include: use of inter-operable and compatible ITS technologies, integration of a full range of ITS products and services, transparent services to users and travelers, and enhanced inter-jurisdictional coordination and data sharing. These types of benefits are discussed next.

BENEFITS OF COMMON DATA, FUNCTIONS AND TECHNOLOGIES

At the level of implementation, the architecture naturally allows those who are planning, funding, designing and integrating ITS components to realize efficiencies as ITS products and services are implemented over time. The resulting synergy may be attributed to systems engineering within the national architecture. Below, we present this synergy across four different areas: common functions, necessary shared information, other shared information, and common technology.

Common Functions

Certain functions may be performed at several different levels of technical sophistication within the architecture. In some cases, a function performed in what might be considered a “basic” ITS market package may in turn also be performed in a more “advanced” market package. As an example, “broadcast traveler information” is a market package providing basic functions to disseminate real-time traffic information. The “interactive traveler information” market package, in turn, may use this existing communication channel to provide more advanced, two-way information services. In this way, more advanced market packages provide incremental improvement on the basic market packages. In other cases, ITS market packages simply share functions, but no hierarchy is implied. For example, both “surface street control” and “incident management” require roadway surveillance capabilities, but there is no direct dependence between the two packages. Summarizing, efficiencies are achieved when market packages using common functions are implemented, because the desired functions can be shared between the packages. The benefits of this synergy to ITS system designers and planners appear in two areas:

1. <u>Efficiencies in functional performance:</u> In the architecture, a given function may appear in multiple packages that in a system design only needs to be performed once. This means that potential redundancies in data collection, processing, and dissemination in an ITS system design can be avoided. These efficiency benefits take the form of cost savings in avoiding functional duplication.
2. <u>Cost savings from common technology.</u> When implementing packages with common functions, only one package containing the given function is required. In this way, the second (or third, etc.) market package that uses these common functions can leverage an existing technology (software, hardware, communications, etc.) investment.

The distinction between these two kinds of benefits is subtle but important. Efficiencies in functional performance are directly attributed to the architecture-level system engineering and integration that has been performed as part of the national architecture development. Benefits of leveraging existing or proposed common technology, however, are directly attributable to the efficiency of a specific ITS system design.

Necessary Shared Information

A second area of synergy comes from sharing information between market packages. In many cases in the architecture, data and information from one market package are used by another market package to provide a user service. In many cases, this information flow is deemed necessary in the architecture, meaning that the provision of one market package is largely dependent on information from the other market package. As an example, network surveillance information is necessary for many market packages, including interactive traveler information, regional traffic control, and incident management (among others).

Specific benefits to ITS implementors occur through coordination of data sharing when multiple market packages are being implemented. Again, benefits may accrue in two areas:

1. <u>Efficiencies in information management:</u> In the architecture, specific data collection, processing and dissemination may be managed so that numerous market packages have access to the same pool of data and information. Efficiency benefits take the form of cost savings in avoiding redundant data bases and data management processes.

2. Cost savings from common technology. When implementing market packages that may share information, cost savings from the information system design and development can be achieved. Multiple users can leverage an existing investment in information technology (e.g. data base management software and hardware).

Again, the distinction between these two types of benefits is that the efficiency of information management is directly attributable to the architecture, while common technology is a function of a specific deployment.

Other Shared Information

In other cases in the architecture, information may be shared between market packages that enhances, but may not entirely be critical, to the performance of specific services. One salient example might be the coordination of surface street control and public transit operations: information on road and transit network conditions can be shared between public agencies. From the perspective of benefits, these data and information flows can be used for better transportation system management and operations. Hence, the sharing of transportation system performance data through the architecture may lead to more effective use of scarce transportation resources and better system-wide planning.

Because the architecture is a fully connected system, information sharing is possible between all major center subsystems for the purpose of enhancing transportation management and operations. Given this level of connectivity that is inherent to the architecture, the types of benefits that may be realized are will occur in system design and deployment. Benefits of system integration include:

1. Improved data collection and utilization: an integrated transportation management system may reduce costs of obtaining, processing, and disseminating data, because of reduced duplication of effort and increased sharing of information.
2. Improved system performance: Traffic congestion, energy consumption, and air pollution may be reduced as a result of synchronized operations, such as smoother traffic flow, faster incident response, and coordinated traffic diversion plans.
3. Increased reliability of the overall transportation system: An integrated system facilitates the development of a set of coordinated plans and procedures to handle different incident situations.
4. Enhanced opportunities for cooperation: Productive, cooperative partnerships between public sector agencies, and between the public and private sectors, may be promoted by having a common technical platform.

Common Technology in System Design

Finally, data flows and functions specified in the architecture may be combined, in a specific system design, to leverage common technology. It is important to keep in mind that the architecture itself does not specify the specific technologies that may be used. The national architecture does identify common functions and shared information, but it does not specify possible system designs that may aggregate different architecture flows into a common media. Nonetheless, the comprehensive nature of the national architecture does suggest that there is synergy in using common components and communications technologies for many of the ITS market packages. Several salient examples of technologies that are good candidates for common applications could include:

- Transportation technologies: Traffic sensors, vehicle system monitoring technology, etc.
- Communications: Broadcast and two-way interactive communications, dedicated short-range communications, wireline services.
- Information management: Data base and information management systems, map data bases, local and wide-area networks, distributed information systems, etc.
- Other technologies: Electronic payment media, location / position determination.

The technologies have applications across a broad range of ITS services.

BENEFITS OF OPEN INTERFACE STANDARDS

One of the assumed keys to system integration is the development of product and interface standards for ITS. It has been presumed throughout the architecture development program that one of the primary benefits of the national system architecture is to identify key areas for ITS standards and to propose the requirements for such standards. The analysis presented in this section articulates the primary motivations and potential impacts of ITS standards. In this way, the benefits of the national ITS architecture from the perspective of interface standards can be understood.

The national architecture program has provided several "standards development packages" that present substantial raw material for standards development organizations (SDOs) to begin their efforts. In this regard, the national architecture may be credited with reducing the initial system engineering and systems integration groundwork that is necessary for virtually any standards development process. This has two effects: it may reduce the time to develop standards; and, it may assist in scoping of appropriate message sets and interface definitions for the SDOs.

User Benefits and Disbenefits

To begin, there are significant benefits and possible disbenefits for end users in having ITS standards. For the end user, several technical benefits of standards are widely cited in the realm of information technology. First, *portability* implies that ITS components, hardware, software and other services may have "plug and play" capabilities. With a set of standard interfaces, products and services can be moved easily between specific operating platforms, communications media, or from one subsystem to another. Second, the standard set of ITS interfaces allows products and services to operate in conjunction with other products and services, providing fundamental *inter-operability*. The national architecture specifies the inter-connections between subsystems, allowing a wide variety of equipment and services to operate in conjunction with other ITS components and services. Finally, in the same way that interface standards achieve inter-operability, they also allow *data exchange* between different ITS services. The value of this data is enhanced by having either "standard" data definitions between applications or standard interfaces that allow unambiguous translation of data from one application to another.

ITS users may also receive economic benefits from standards. In the long run, standards may lead to an *expanded choice of products*. By defining an interface, product and service vendors can focus on supplying components that meet these interfaces, without worrying if their components will be compatible with other vendor's products (i.e. without worrying about inter-operability). With ease of product compatibility, a larger choice of products is likely to ensue. Thus, vendors can satisfy a wide variety of end user needs and tastes. Second, standards allow certain *economies of scale* in production of products and services in the market as a whole. In general, such lower costs of production across vendors will lead to lower costs to consumers. Third, several ITS services may result in *network externalities* from common user interface standards. In addition to the economies of scale, there is the added effect that a larger user base (i.e. a larger network of users) will lead to direct increases in benefits. The network externalities occur when a larger pool of users increases the level of service to each individual user. Examples in ITS include: route guidance (more users of optimal routing improves each driver's travel time); dynamic ride-sharing (a larger pool of users increases the likelihood of a shared ride); and, yellow pages and reservation (the more participants, the better information for travelers). Finally, users benefit from a *shorter learning curve.* In the long run, standard product features and interfaces have the added advantage that less time is required to train personnel how to use a particular product or service, since it is likely to have common features with other products that people already know.

At the same time, open interface standards mentioned above may also lead to undesirable impacts for users. In particular, for the end user, the existence of ITS interface standards may lead to problems in terms of costs, technology compatibility, and long-term technology innovation. In the short term, early adopters of standards may, by the nature of an uncertain market for compatible products, pay considerable costs for "standardized" products and services. The financial costs for these early adopters can be substantial. In many cases, the initial price of a standardized product may be significantly higher than other (e.g. proprietary) existing systems. Also, if a market does not fully materialize, the early adopters may also face very high costs of operating and maintaining the system.

More significantly, in the long term, the standards-setting process can lead to a choice of technology that is, in the longer term, inferior to other existing or emerging technologies. This may directly influence the long-term costs of purchasing, operating and maintaining the specific ITS products and services. That is, one may argue that the costs associated with alternate technologies may be lower that those associated with a standard. Also, adoption of a particular ITS standard does not necessarily imply that products will be compatible in the long run. First, if the standard is not universally adopted, early adopters may be "orphaned," with the result being high costs of operating, maintaining, and ultimately replacing the obsolete product. Second, given the rapid rate of innovation in information technologies, the life cycle of a particular product or service may outlast the value of the standard. That is, longer-term cost savings and compatibility may not be realized if the standard is obsolete before the technology needs to be upgraded or replaced.

Vendor Benefits and Disbenefits

The adoption of industry consensus standards may lead to benefits for some ITS product and service vendors and clear disadvantages for others. From the perspective of all vendors, standards may serve to *ignite markets*. In many cases, the existence of an industry-wide standard may be a key element in initiating a market. The existence of a standard allows significant economies of scale in production, bringing prices down sufficiently to have a market "take off." Having a standard may allow the development of a market where virtually no market existed before. In addition to igniting new markets, the system compatibility that results from consensus standards may lead to *market expansion*. A diverse and expanded choice of products for a particular market may be developed, as vendors take advantage of variations in user needs and tastes. Finally, standards support new *technology insertion*. The specification of ITS interface standards means that new or innovative technologies that are compatible with the interface may be introduced. In this way, new technology innovation may be stimulated.

At the same time, standards may also have significant impacts on vendors and on the ITS industry as a whole. From the perspective of market profitability, open standards typically lead to significantly greater price competition for compatible products. Profit margins for vendors with proprietary or off-the-shelf integrated solutions are thus likely to decrease. At the same time, price competition has obvious benefits for end users. Secondly, considering technology innovation, standards often inhibit innovation for technologies that are defined within the standard. That is, they "lock in" particular technologies, and such choices are often difficult to change. In addition, they may eliminate other cost-effective or technically superior options (e.g. other emerging technologies, gateways, etc.). Third, interface standards generally allow a wider variety of products and services to be offered, leading to a "level playing field" between both large and small vendors. In addition, as interface standards are adopted, the need for vertical integration of businesses to provide products and services decreases. These market forces may yield greater economic productivity from vendors, and cost savings to the end users.

Summary of Standards Impacts

Through open interface standards, the national ITS architecture has as its goal to provide a technical framework that will allow the development and long-term sustain-ability of a market for ITS. One of the main tools to achieve such market effects is to develop open interface standards for ITS products and services. Such standards may provide desired levels of compatibility, inter-operability, and cost savings that users need. On the other side, standards may help initiate and enlarge markets for ITS products and services, enhancing private vendor participation. Open interface standards may also spur considerable technology innovation in meeting user needs and tastes, and may also allow expansion to new technologies as they evolve. At the same time, the analysis above suggests significant risks and costs for both users and vendors associated with these efforts. While it is widely held that the benefits of such standards greatly exceed the costs, there is a need for more qualitative and quantitative evidence to support this evaluation.

CONCLUSIONS

The national ITS architecture provides benefits to ITS by providing a common framework for systems development, design and integration. A major benefit of the national architecture is the extent to which the architecture supports integration of transportation functions, information flows and technologies. This integration is possible because the national architecture results from a comprehensive systems engineering effort to address the widest possible range of ITS services. The benefits of this integration include: (1) data sharing for system management and planning; (2) common functions and functional integration; (3) common technology; and, (4) open interface standards. The architecture provides a framework of data flows and functions that allows system integrators to design a system that is efficient in its collection, processing and dissemination of data. Moreover, these data allows us to manage the transportation system more effectively through better intelligence on the system's performance. System implementors may also leverage existing and planned investments in technology to perform many of these common functions. Finally, the development of open interface standards will provide compatibility for ITS consumers. In addition, these standards will encourage competitive markets for ITS products and services, allowing cost savings for both users and vendors. In these ways, the national ITS architecture provides a beneficial framework to guide ITS development and deployment over the next 20 years.

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