Integration of GIS-T and IVHS: Key to Success

D. David Moyer
National Geodetic Survey
Wisconsin Department of Transportation
University of Wisconsin
Madison, Wisconsin, USA

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Introduction

Geographic information systems (GIS) have developed rapidly in recent years for many uses and users. Our experience in the United States of America is that GIS for Transportation (GIS-T) systems have become one of the standard tools which many State departments of transportation, as well as Federal transportation agencies, rely. In the last two or three years, Intelligent Vehicle Highway Systems (IVHS) have also exploded on the scene. In this paper definitions for GIS, GIS-T, and IVHS are presented, the reasons for the recent development of these systems discussed, and the opportunities for additional benefits through the integration of GIS-T and IVHS efforts suggested. Throughout, the principle focus of this paper is on the institutional and organizational aspects of development and use of GIS-T and IVHS systems.

Background

Geographic Information Systems (GIS) Defined

The term geographic information system (GIS) has been described in a variety of ways by various authors. Some limit the meaning to include only hardware and software, some add data, and others include the people and institutions that are necessary to develop, maintain, and use the system. In this paper, the definition of GIS systems developed by Dueker and Kjerne is used. A geographic information includes "a system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth." (Dueker and Kjerne) As Parker has noted, "a GIS is more than just a special kind of information system ... [i]t is a technology." (Parker, 1988, p. 1547)

Geographic Information Systems for Transportation (GIS-T)

The above definition of GIS is focused on "areas" of the earth, with the implication that polygons and parcels are the major component of the GIS. When transportation layers are included (i.e. GIS-T), various transportation networks are added, including highways, rail corridors, waterways, bicycle trails, etc. Inclusion of transportation networks with all of the other point, line, and polygon data that make up GIS systems is what makes GIS-T such a powerful tool. In sum then, GIS-T is a technological approach for the acquisition, handling, and use of spatial data.

We should note that the term GIS has generally been limited to spatial data handling systems that include the analysis capability. Until recently systems such as computer aided mapping (CAM) and computer aided design (CAD) did not include this analysis capability. Recent versions of software for several CAM and CAD systems now have analysis capability, so that the distinction among GIS, CAD, and CAM systems is becoming more blurred with the passage of time.

Intelligent Vehicle Highway Systems (IVHS)

Intelligent Vehicle Highway Systems (IVHS) technology is related to GIS and is being developed as a national program in the United States of America to harness the latest spatial data handling technology for a variety of transportation related purposes. IVHS includes the "areas of communications, navigation, and information systems in order to reduce traffic congestion, to increase transportation efficiency, to enhance mobility, to improve highway safety, and to reduce harm to the environment caused by automobiles." (Sweeney, p. 22) I would expand this definition to include not only automobiles, but also buses, trucks, and other fossil fuel powered vehicles, since many parts of IVHS will help reduce environmental damage in these areas as well.

The components that make up the entire IVHS field include:

1. Advanced Traffic Management Systems (ATMS)
2. Advanced Traveler Information Systems (ATIS)
3. Advanced Public Transportation Systems (APTS)
4. Advanced Vehicle Control Systems (AVCS)
5. Advanced Rural Transportation Systems (ARTS)
6. Commercial Vehicle Operations (CVO)

While it is not possible to go into detail on each of these components here (and I assume others at this conference will do so), it is important to note that these six components include a wide variety of cutting edge technology, capable of being combined in many ways to address both current and projected needs for management of the full range of transportation systems.

To understand the extent of IVHS and it's potential as a comprehensive transportation information system, it is useful to consider, at least briefly, some of the potential applications and some of the technology that are being proposed for IVHS systems.

ATMS

For instance, Advance Traffic Management Systems require a variety of sensors to locate points of congestion, accidents, and to manage traffic flows using traffic lights, ramp meter, and message signs that can be changed from a central location. (Sweeney, p. 26)

ATIS

Advanced traveler Information Systems provide both the capability to do advanced planning for trips as well as to make "on-the-fly" decisions during a trip. The output of pre-trip planning includes finding the route that is the shortest, or fastest, or the most simple and/or providing a detailed listing of instructions on how to follow a particular route. (The latter is sometimes provided by rental car companies or other travel planners.)

Vehicle navigation systems also are part of ATIS. Included are systems that take over the guidance of the vehicle. However, ATIS also include a variety of additional potential capabilities, including real-time vehicle tracking and map display within the vehicle that rely on a technology such as Global Positioning Systems (GPS), inertial navigation, and electronic "beacons" along the roadway.

APTS

Public transit systems (including buses, subways, trains, ferries, and taxis) are the focus of Advanced Public Transportation Systems. APTS use technology similar to the ATIS system, except here it is applied to systems that transport multiple numbers of people in each vehicle. These systems provide flexibility for transit systems, providing the means to alter schedules to keep transit vehicles properly spaced, and even to advise riders of changes is schedules (Sweeney, p. 28).

AVCS

Advanced Vehicle Control Systems include a variety of technologies that range from automatic vehicle spacing to auto-pilot of individual vehicles. Auto pilot is the technology upon which most media stories focus. It is also the most futuristic application and will likely require the longest time to come to fruition.

ARTS

Advance Rural Transportation Systems are a fairly recent addition to IVHS. ARTS systems have been added because of the "disproportionate share of fatal accidents [that] occur on rural roads" (Sweeney, p. 30). ARTS systems need to address a variety of problems, including collisions with animals and slow moving vehicles (e.g. farm machinery, farm animals, and non-domesticated animals such as deer in many parts of the United States); vehicles leaving the roadway due to excess speed, limited visibility due to terrain, and drivers falling asleep; and weather-related accidents (due to excessive rain, snow, ice, fog, dust.) Technology proposed as options to deal with these problems include beacons on certain slow moving vehicles, stationary electronic controls that provide drivers with both verbal and audible warnings, and beacons in cars that help locate accident victims in isolated areas or after the vehicle has left the roadway (and often is not visible from the roadway).

CVO

Commercial Vehicle Operations provide technology to address a number of problems faced by commercial fleet operators and emergency vehicles. Real-time vehicle tracking, dispatching, routing, scheduling, automatic toll-taking, weighing trucks in motion, and locating stolen vehicles are few of the applications being proposed. Several long haul freight companies in the United States of America have active programs in this area already. Schneider International of Green Bay, Wisconsin is leading the way in systems that provide real-time location, communication, scheduling, and dispatching. J.B.

Hunt of Lowell, Arkansas has recently added two-way message relay systems that combine L-band satellite and GPS positioning to 1,000 of their trucks (Automotive News, p. 16).

IVHS

It is obvious from this overview that Intelligent Vehicle/Highway Systems (IVHS) are much more than a single system or a single approach to planning and managing a transportation network or system. In fact, Luchian argues that IVHS is really "the application of a group of technologies - including computers, communications, electronic devices, and integrated systems - to improve the safety, mobility, and convenience of the traveling public" (Luchian, 1994, p. 62). To deal with this many faceted program, the Federal Highway Administration (FHWA), part of the U.S.DOT, working with IVHS America, a private sector transportation trade group, has identified the six functional areas, discussed above, that make up the current family of components and applications that a fully developed IVHS could support.

Greater details on these components and applications will be left to other speakers at this conference. It is sufficient to note here that the scope and possibilities from this technology are substantial. As noted earlier, applications are expected to range from better plans to reduce highway congestion to high technology solutions, such as electronically controlled highway and vehicle systems that can be combined to provide complex navigational systems.

WITH SO MANY POTENTIAL BENEFITS, WHY SO LITTLE PROGRESS?

The complexity of the concepts and the relative infancy of both GIS-T and IVHS systems have delayed consensus as to precise definitions of these systems. The lack of agreement on definition in turn leads to uncertainty as to the best development path to follow. Also, because of this complexity, there are several viable options for defining and describing the systems themselves. For example with IVHS, the first efforts by the U.S. Congress to address opportunities of IVHS, the U.S. Department of Transportation (DOT) developed a strategic plan that "described the goals, objectives, and milestones of the IVHS program from a technology standpoint" (Thompson, 1994). In an effort to further refine the definition of IVHS, the U.S. DOT and IVHS America have also used the functional area approach, discussed above, to articulate the scope and potential capabilities of IVHS.

Probably as important, relative to slow progress in GIS-T and IVHS system development, is the failure of all parties involved in the GIS-T/IVHS arena come to grips with a number of key issues. These issues relate primarily to institutional and organizational aspects of GIS-T/IVHS systems: how will the systems be organized and operated (i.e. who will develop, operate, and maintain the system, especially the data base; do agencies recognize and commit to the fundamental changes in organizational structure and operation methods that are necessary in the way they do business; is there a commitment of the substantial resources needed for education and training (a commitment that is a continuing one for the foreseeable future); and is there a commitment to data sharing among all system users (necessary if the substantial potential benefits of a GIS-T/IVHS system are to be realized)?.

Unless these issues are addressed at the outset of system development efforts, progress is likely to move forward very slowly, if at all.

DATA SHARING AND INSTITUTIONAL ARRANGEMENTS - THE BIG HURDLE

The definitions for GIS and IVHS set out earlier make clear that there is much similarity surrounding the needs, goals, and technologies required for these two "systems". Similarly, there is substantial overlap between the data needs of GIS-T and IVHS. Finally, a substantial effort in terms of time and costs will be required to populate the data bases needed for these respective systems. Therefore, there are many common issues and concerns that apply to both GIS-T and IVHS systems. At the same time, progress in systems development and implementation, particularly as related to GIS-T, have not been as rapid as the needs for and potential benefits from these systems would suggest. One of the premises of this paper is that the GIS-T and IVHS systems need to be developed and maintained in at least in tandem, if not as a single, composite, system, if the benefits of these systems and the data they contain are to be fully realized. A second premise is that failure, thus far, of GIS-T systems to produce the level of benefits expected by many, is the result of our failure to understand and give adequate attention to the institutional and organizational aspects of GIS-T systems. In the next section of the paper examples of institutional issues are defined and discussed.

Institutional Issues Defined

Perhaps one reason for the lack of adequate attention to institutional issues is the lack of a clear, simple of definition of the term "institutions". This is true in spite of a number of very competent researchers and commentators who have addressed the subject. However, as used here, institutions refer to organizations, agencies, and private establishments that are considered part of a GIS-T or IVHS. Institutions also include the laws, rules, customs, and practices by which the various spatial data handling activities are carried out in an organization. (Wellar, 1993, p. 208)

As Wellar has suggested (Wellar, 1993, p.210), in many cases, it is not possible to clearly separate institutional issues from other factors. For example, often institutional issues such as privacy, confidentiality, access to data, and standards are also organizational issues as well. Similarly, the distinction between institutional and organizational issues as used in this paper is often imprecise.

Institutional Issues

Issues that I would suggest be included as institutional for purposes of our discussion include: identifying participants, multi-agency (multi-participant) agreements, management structure, system structure (centralized or network), data custodians, system monitoring, system maintenance (who, and with what frequency), resistance to change, autonomy of agencies, education/training support, management support (top level), political support, standards (hardware, software, data, etc.), geo-referencing framework, data sharing (does data exist, at what scale, in what format, on what medium, etc.), data collection, (what items, what resolution, what accuracy, what currency, etc.), data quality, funding options, shared costs, cost recovery, end user pricing, legal issues (privacy, confidentiality, data access and liability, etc.), public opinion, public confidence, and implementation strategies (i.e. evolution of system over time). Even this substantial list is not an exhaustive one – rather it is indicative of the kinds of issues that fall into the institutional arena. The list is illustrative of the level of complexity presented by many institutional and organizational issues. The remainder of the paper will consider several of these issues in greater detail.

Institutional Issues and Their Impacts on GIS-T

If nothing else, the above list attests to the complexity of institutional aspects of GIS-T systems. As multipurpose becomes an increasingly important aspect of GIS systems, the complexity of institutional issues involved increase as well.

Multi-agency Coordination

The sharing of a common data base is often a key factor that brings agencies, divisions, etc. together to support a multipurpose land information system (MPLIS). (See for example, the discussion in Brown and Moyer, chapter 7). One example of an MPLIS model is shown in Figure 1. This model relates specifically to land information systems, but as noted earlier, it is equally applicable to systems that include transportation networks as well. For many uses in fact, it is important to be able to combine data from transportation networks with other point, line, and polygon data that make up the typical MPLIS. Suffice it to say that multipurpose systems, used by a variety of agencies for a variety of purposes, introduce additional institutional complexity into GIS-T systems. It is duly noted that even the most elementary GIS-T systems are not simple, even in their most elemental form.

The key to successful MPLIS/GIS development, implementation, and use is a clear, broadly supported plan. This plan should address as many institutional issues (as well as technological issues) up front. This will allow system users and operators to concentrate on solving unforeseen problems, and not become bogged down dealing with issues that could have or should have been foreseen.

Earlier a large number of institutional issues were iterated. Several are worthy of further discussion, given their importance as a foundation for a successful MPLIS/GIS. Among the foremost of these issues are identifying who will be involved and how they will be organized.

Identifying Participants

Two key factors should be considered as to MPLIS systems such as those that are used for GIS-T/IVHS project structure and management. One concerns the decision as to how far to "cast the net". On a conceptual basis, the more people and agencies who are involved, the more comprehensive the resulting system will be, and therefore, the greater the likelihood of the system having the capacity to meet a wide variety of user needs. At the same time, as systems become broader in scope, they also generally become more complex as well.

The second factor concerns the general philosophy of top management concerning the extent that the multipurpose system philosophy will be integrated into the agency, jurisdiction, or state. This is especially true regarding GIS-T and is one of the primary reasons for the relatively long starts-up times and slow adoption rates in many state departments of transportation (DOTs) in the United States.

Integration of MPLIS/GIS-T into Agency

There are two basic approaches that State DOTs (and other agencies) can take as to the implementation of a GIS-T. One approach is to assume that a GIS-T is another tool, technology, technique, or procedure, and treat it as such. This approach is similar to the one used for things such as word processing, copy machines, and stand alone personal computers (PCs). Each of these items helped improve productivity and improved the quality of the product or service that was generated.

The second approach is to fully integrate MPLIS/GIS-T into the agency, which means changes, often radical, in the way we organize ourselves and the way we operate as a agency. Many of us believe this latter approach is the one required if the major benefits of MPLIS/GIS-T are to be fully realized. This approach means a more difficult transition period, because many changes, some of them major, are required. Fletcher has in fact referred to GIS-T as a "disruptive technology", to indicate the relatively radical nature of the institutional changes that are needed (Fletcher, 1993).

These changes include such items as basic organizational structure (with changed relationships and new lines of command). Individual jobs, sections, and bureaus change. New technology and data responsibilities (for collection, maintenance, storage, and use) are introduced. These changes in turn require not only organizational changes, but also require additional training and education of employees. Also, the very nature of GIS technology, with new hardware typically available every 12-18 months and new software available every 2-5 years, means that the training and education are on-going, not one-time requirements. Changes of this magnitude within a DOT also produces changes, at least in operating procedures and possibly in structure as well, with outside agencies with which DOTs do business.

Given the power of MPLIS/GIS to assist in the solving of problems related to land, natural resources, and networks, many believe that over the long run the more comprehensive kinds of changes are the ones we can expect to occur. This suggests that a useful approach is to assume such major changes will occur, and concentrate management and system development attention on **how** these changes will be made, rather than **if.** We also need to consider how to best move from our current systems of handling spatial data to the comprehensive MPLIS/GIS-T models. Again the complexity of current and proposed systems, as well as the importance of the data, information, and decisions that flow from these systems, suggest a gradual, iterative process. Such an approach should be less disruptive, provide needed applications support during the transition, and provide the time (and other resources) needed for training of staff.

Resistance to Change

A number of barriers or constraints exist to changes that an MPLIS/GIS-T system typically requires. Anyone planning such a system should consider the existence and importance of these barriers in their environment, and develop plans to deal with each one. Among the barriers to watch for are:

- A general resistance to change.
This may be due to traditional practice, statutory requirements, etc.

- Lack of familiarity with new or the latest technology.
System developers need to be reasonably familiar with technology, in order to design the institutional framework necessary to support the system.

- Lack of education and training support.
Education and training of staff must be addressed up front. Also, funds for training will be necessary on a continuing basis, the need will not stop just because the system is successfully implemented.

- Lack of top level management support.
Such support is needed both to get project underway and then to keep the system successfully operating over the long run. Many successful system implementations in Wisconsin can be traced directly to support of county executives, state agency cabinet secretaries, and at least two Governors of the State.

- Multi-disciplinary effort required for many MPLIS/GIS-T activities.
This is not always possible and never easy. However, the most successful systems in operation have found ways to obtain cooperation, on the working level, for a variety of disciplines.

Common Shared Data Base

By their very nature, both GIS-T and IVHS systems will require sharing of data - that is each of these systems is in fact a multipurpose system. By virtue of being a multipurpose system, data sharing among multiple users and uses is assumed and even required. Multiple use is assumed since costs of collecting, maintaining, updating, and accessing data can be reduced if there is a cooperative effort made as to the data base on which these systems operate. Second, the overlap between GIS-T and IVHS systems suggests that many, if not most, of the data needs of the two systems rely on very similar sets of data. Third, the effectiveness of the systems themselves depend on an integrated data base. For example, there are numerous overlaps in data needed for the six components or areas of the IVHS laid out earlier in this paper. In order to build a safe, efficient IVHS system, an integrated data base, used by all components or subsystems, is critical.

Data sharing is one of the primary approaches for economic justification of many MPLIS and GIS-T systems. This is logical since most data handled by governments (especially at the local level) have a spatial component. Second, data costs, for conversion and data base construction, typically account for 75 to 85 percent of total MPLIS/GIS-T system costs. Third, maintenance of data bases will continue to require a major proportion of resources (dollars, personnel, time) for operation of the system. Maintenance of the data base is critical if the system is to continue to provide relevant, accurate, timely data and information for system users.

It is important that the goal of data sharing be embraced by all participants in the MPLIS/GIS-T system, since this is the aspect through which a substantial portion of the benefits of the MPLIS approach will flow. That is, an MPLIS/GIS-T is not likely to produce any significant reduction in the costs of current activities. However, the MPLIS approach will enable the agency to stabilize costs, and more importantly, provide the comprehensive data base necessary to address increasingly complex problems which governments are facing.

Once agencies are committed to the sharing of data, mechanisms need to be put in place to facilitate the sharing. For instance, potential data users will want the answers to several questions, such as: does the data I need exist, at what scale was the data collected, at what scale can maps be produced from the system, in what format is the data available, on what medium(s) is the data available, and how often are data updated (currency)?

Data Collection

In MPLIS systems, a number of decisions are important, to help assure the greatest use (benefit) to as many system users as possible. For example, decisions are needed on what data to collect, at what level of resolution, what currency is required (i.e. often is the data base updated), and are all parties committed to a collection process based on cooperation to ensure the common good. (Carter, 1992, p. 1558)

Agreement on these data collection items is important in any multipurpose system. Agreement is especially important as to IVHS systems since the successful operation and efficiency of the IVHS information system requires the coordination of both the technology (hardware and software), but also the data on which this technology operates.

Standards

A related institutional factor is the need for standards. Standards are needed for hardware, software, and data, the latter being the most critical factor system developers must address. (Hardware and software are just as important but are being handled and are controlled, to a large extent, by the vendor companies who produce this technology). Agreements and procedures need to be worked out for: the geo-reference framework to be used, position accuracy, attribute accuracy, data encoding, data exchange (e.g. formats), scale of output, and data quality. By thoroughly addressing these standards issues, the quality of the data base will be improved and the exchange of data will be facilitated.

Funding

One of the key institutional issues that must be faced is how to fund a multipurpose information systems such as GIS-T or IVHS. (Note that funding of development and funding of on-going operation may not be the same.) Given the vertical nature of organizational structure in most governments, even reaching agreement on who pays what within a single agency is often not easy. This is due to the relative autonomy of divisional components within the agency, as well as what are relatively precise, narrow mission statements as to responsibilities of each component (e.g. division, bureau, group, etc.)

A variety of funding options exist, including: cost sharing (on basis of system use, size of data base, geographic area, tax base, etc.), user fees, taxes (property, income, property transfer, recording fees, etc.) bonds, etc. Because each situation where MPLIS/GIS-T/IVHS systems will be developed and operated are unique, developers of each system will need to determine which approach is best. Involvement of a broad cross section of users in this decision is a good idea.

Education and Training

Several kinds of training and education are needed to support the development and operation of an MPLIS/GIS-T system. For example, education is a valuable tool to overcome fear of change. (Ventura, 1993, p. 14-21) Education and training to make everyone concerned aware of the technology and what is planned can be especially helpful in getting staff to support a project, as well as the more general public. Second, training and education will be needed at the outset to train staff, once a decision to implement an MPLIS/GIS-T/IVHS is made. Third, GIS and related systems are built on a rapidly changing, evolving technology that will require on-going training and education of staff. The need for such training must be recognized, planned for, and funded, in order to ensure that staff are fully capable to produce all the efficiencies that this technology allows.

Implementation Strategy

MPLIS/GIS-T/IVHS systems are relatively new, expensive, and continuing to change in scope and capability. While the exact nature of future changes are unknown, it safe to assume that they will continue to occur. Therefore, many people suggest an implementation strategy that is incremental (don't try to do everything at once), and also a strategy that is flexible (to make it possible to take advantages of future changes in technology, organization, and institutions, as they occur). Institutional arrangements that support this approach will make it possible to take advantages of the latest innovations, increasing the benefits to all concerned. (Haynes, 1993. p. 13) This approach will also help prevent surprises of expensive technology becoming obsolete. (Haynes, 1993, p. 7)

SUMMARY AND CONCLUSIONS

This paper discusses one of the most important, most difficult aspects of multipurpose information systems - the institutional and organizational issues that are critical to successful development, deployment, and use of such systems. In this paper we review the definitions of geographic, multipurpose, and IVHS systems, and argue that GIS-T and IVHS are each multipurpose systems that also have much in common with each other.

We suggest that the benefits of GIS-T and IVHS systems are substantial, but that failure to address a number of important institutional and organizational issues is one major reason for failure of these systems to live up to expectations, at least thus far. A number of key institutional and organizational issues are identified and discussed, and suggestions are made as to how to incorporate these issues into the system development process. We conclude that the long run success of GIS-T/IVHS systems depends on coordination and cooperation, particularly as to the data bases that form the foundation for such systems. It is important that we address these issues now, in order to maximize the benefits that will accrue to society in general as a result of these valuable information system resources.

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