Organization for Intelligent Transportation System: Computer-Integrated Transportation

RANDOLPH W. HALL, HONG KAM LO, AND ERIK MINGE

Computer-Integrated Transportation (CIT) is envisioned as an integrated network of public and private transportation organizations, each with unique responsibilities but working toward a common mission of facilitating travel across all modes of transportation. The objective of this study was to evaluate alternative frameworks for CIT from an institutional perspective. This was accomplished through site visits and interview at existing transportation management centers (TMC) along with focus group sessions in which strategies for CIT were presented to TMC managers and staff (only the latter is reported here). The study found that four factors have profound implications of Intelligent Transportation System (ITS) implementation and research: (1) time-frame, (2) linking information to actions, (3) broadcast orientation, and (4) embracing of new technologies.

Advances in information, computation, and communication technologies in the 1970s, 1980s, and 1990s have stimulated remarkable changes in business practices throughout the world. For instance, with the advent of computer-integrated-manufacturing (CIM), it is now possible to track accurately, automate, and control production from the moment raw materials are extracted from the ground until finished products are delivered to customers. Today, intelligent transportation systems (ITS) offer much of the same promise for transportation that CIM held for manufacturing. Encompassing a spectrum of electronic and communication technologies, ITS may one day achieve computer-integrated-transportation (CIT), where both the users and operators of transportation systems can obtain and exchange information effortlessly, to facilitate travel across all modes of transportation.

CIT is envisioned as an integrated network of public and private transportation organizations, each with unique responsibilities, but working toward a common mission of facilitating travel across all modes of transportation. The CIT is designed to achieve effective coordination of the transportation system, while respecting the responsibilities of participating agencies. Within these bounds, the CIT draws on resources (e.g., emergency crews, traffic control, etc.), both internally and externally, as needed to ensure the smooth operation of the transportation system.

The objective of this paper is to evaluate alternative frameworks for achieving CIT from an institutional perspective. To this end, existing transportation management centers (TMCs) both in California and around the country were surveyed in depth to assess existing capabilities. Site visits were conducted at all Caltrans TMCs as well as at three city TMCs (Anaheim, Los Angeles, and San Jose) (*1*). These interviews were followed up by a series of four focus group sessions, in which strategies for CIT were presented to TMC managers and staff for their comment and discussion. Finally, a follow-up survey was administered to each TMC to assess future directions for California TMCs. The initial survey, focus groups, and follow-up surveys are the basis for our evaluation of alternative frameworks for CIT. In-depth results are provided in Hall et al (*2*). Because of length restrictions, this paper focuses on the focus group aspect of the study.

The remainder of the paper is divided into seven major sections. First, the concept of CIT is introduced, along with key organizational issues associated with CIT. Next, a literature review is provided, concentrating on organizational designs for transportation management centers, and issues in CIM. This is followed by summarized results from focus groups with TMC personnel. Finally, survey and focus group findings are interpreted and recommendations are provided on how to implement CIT.

LITERATURE REVIEW

By far the most extensive study on TMC organization is a report by Booz-Allen and Hamilton, *Institutional Impediments to Metro Traffic Management Coordination* (*3*). The study includes a literature review on organizational theory and TMC practices, as well as results of interviews with TMC personnel in six metropolitan areas. The study further provides a list of 30 recommended solutions, most important of which include developing a "vision of evolutionary ATMS [Advanced Traffic Management System] implementation" and developing "work plan guidelines for implementing ATMS" ("a step-by-step 'cookbook' approach for implementing one, or more, ATMS technologies in an area").

Carvell et al. (*4*) provide a case study on improving interagency coordination, based on a traffic signal control project in North Dallas County. The project avoided disagreements by first creating a multi-agency steering committee and then developing guidelines aimed at promoting cooperation. These included funding restrictions (only supporting projects that would benefit multiple cities), procurement coordination (cities used normal procurement procedures, but submitted documentation to the steering committee for approval), and hardware flexibility ("cities were free to use their own controller specification but it had to contain minimum criteria").

Other relevant research includes papers on ITS system architecture. Varaiya (*5*), for instance, describes a layered structure that, to a degree, also defines an organizational structure. However, Varaiya's work is not directed at the institutional issues that arise in

R. W. Hall, Department of Industrial and Systems Engineering, University of Southern California, Los Angeles, Calif. 90089. H. K. Lo and E. Minge, Partners for Advanced Transit and Highways, University of California, 1301 S. 46th Street, Richmond, Calif. 94804.

cross-jurisdictional coordination. Hall (*6*) proposed a framework for defining transportation architectures that spans modes (for both goods and people). He classifies architectures along the dimensions of communication medium (e.g., audio, visual, electronic, mechanical, and verbal/nonverbal), assignment of functions to transportation entities, and degree of coordination. This framework will be used in structuring organizational designs within the proposed work. The National IVHS (Intelligent Vehicle Highway System) System Architecture project has produced a variety of documents defining lines of communication between organizations (*7*) but not addressing specifically organizational responsibilities. As part of this effort, Rockwell International's document on evolutionary deployment (*8*) discusses how user services might be bundled into market packages and deployed over 5-, 10-, and 20-year time scales but does not address organizational responsibilities.

ORGANIZATIONAL ISSUES

This section is divided into three sub-sections: organizational structures, assignment of ITS functions, and internal organization. These concepts served as the framework for focus group discussions and address strategic issues in the design of CIT.

Organizational Structures

The organizational structure defines responsibilities by jurisdiction and defines the patterns of coordination and communication. The goal is to enable both public and private agencies to work effectively with each other. Two fundamental alternatives are "leadership" and "decentralized" structures, as discussed below.

Leadership Structures

Under this vision, certain transportation management centers are designated (or created) to act as leaders among satellite centers. Coordination may occur at any of several levels, ranging from simple exchange of information and responding to requests to active control. Leadership can be defined on a functional basis or on a locational basis, as discussed below.

Functional Leader

For a metropolitan region, the functional leader is responsible for coordinating a function, such as arterial signal control, incident response, traveler information, etc. (Figure 1). The leader TMC is activated when there is a need to pull together resources across jurisdictional lines or to synchronize across jurisdictional lines.

Locational Leader

Within a district, the locational leader is responsible for coordinating all functions (Figure 2). The leader TMC is activated when there is a need to coordinate resources across functions. Locational leaders communicate as equals with each other. For example, a locational leader might be responsible for coordination of all ITS functions (signal control, traveler information, vehicle identification, etc.) within a county. Its satellites could then be TMCs that specialize in particular ITS functions that serve the county.

Decentralized Structures

Under this vision, no TMC is designated as a leader (Figure 3). Coordination is achieved through exchange of information, perhaps accompanied by protocols as to how one jurisdiction should respond to another (in a manner like mutual aid pacts for fire districts). However, no TMC assumes leadership over others.

Information Exchange

The type of information exchanged between agencies and the protocols in place for how an agency responds define the "degree of coordination." The degree of coordination is a spectrum with control at one extreme and isolation at the other. Lo et al. (*1*) identify four steps in this spectrum:

- Coordination via occasional meetings, phone calls, faxes or electronic mail;
- Established data links among TMCs, so that the TMCs can observe each other's real-time traffic patterns and controls;

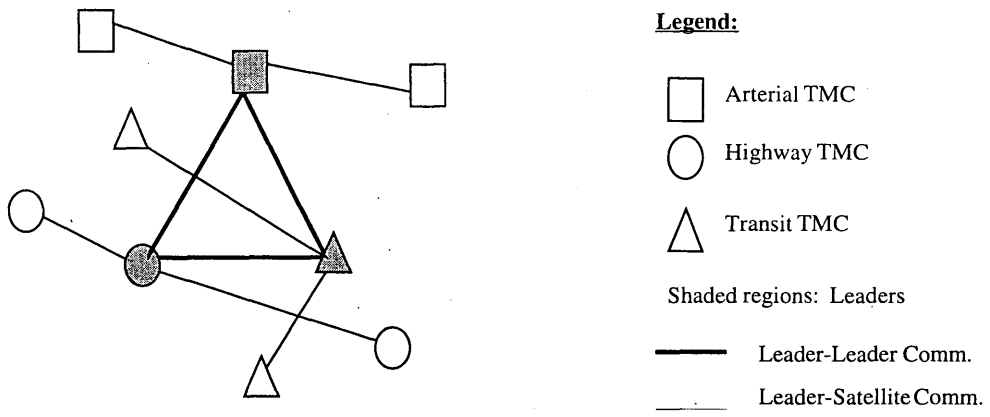

FIGURE 1 Organizational structure for functional leadership

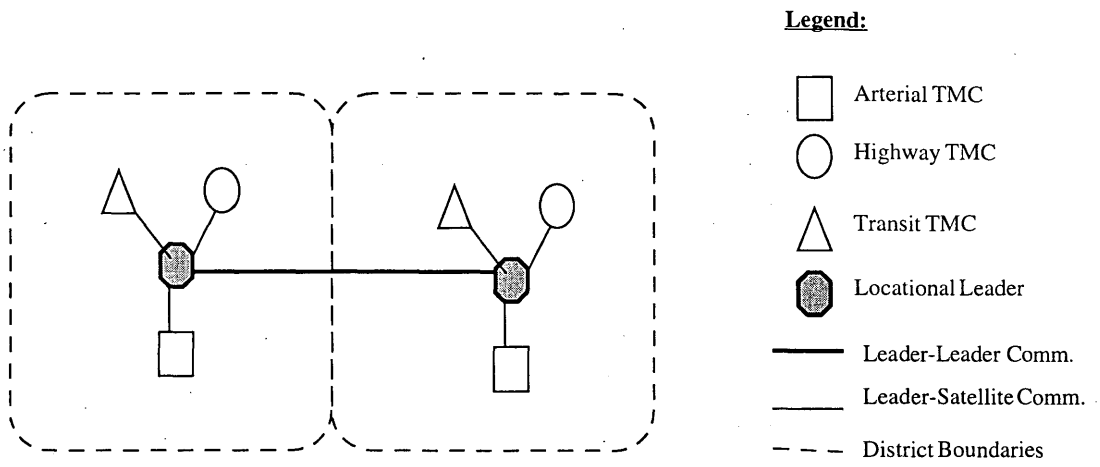

FIGURE 2 Organizational structure for locational leadership.

- TMCs not only observe each other's patterns but respond to patterns of external agencies through prescribed protocols; and
- TMCs not only exchange information, but TMCs are empowered to issue commands to external TMCs under prescribed conditions (such as from a leader to a satellite).

Assignment of ITS Functions

The CIT should be capable of providing a range of ITS functions today and be flexible for expanding to new ITS functions as they are developed. The organizational structure provides a framework for determining where and how these functions are implemented and coordinated. As an ideal, such a framework would remove these decisions from the burden of political wrangling and speed the adoption of ITS.

Managerial Reporting and Control

This category of functions is aimed at long-term improvements in the transportation system. Through daily, weekly, monthly, and annual reporting on system performance (including accident statistics, travel times, on-time performance, patronage, congestion, etc.), the reporting system draws managerial attention to the most urgent problems, and speeds their resolution. Managerial reporting relies on a range of ITS technologies, most importantly surveillance, communication, and management information systems. Most importantly, managerial reporting offers the impetus for continuous improvement in overall system performance by drawing attention to the most critical problems.

Operational Control

The minute-to-minute decisions needed to keep the transportation system up and running, at maximum efficiency, fall in the category of operational control. *Normal Operational Control* pertains to operation in the absence of unusual disturbances or incidents. Mostly these functions do not require human intervention. Examples include adaptive signal control and automated toll collection. *Incident Based Operational Control* pertains to operation in the event of accidents, adverse weather, stalled vehicles, etc. These functions ordinarily demand human intervention, both at the site

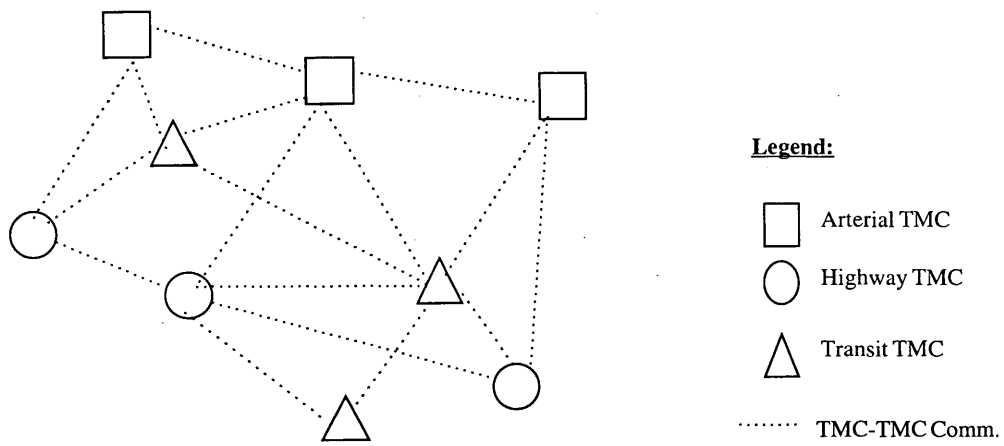

FIGURE 3 Decentralized organizational structure.

by incident response crews and at the TMC, to direct the response, employ changes in signal plans, and send out traveler advisories.

Internal Organization

Within any organization, an ITS function can be implemented in a variety of ways. It might be centralized at a management center, or it might be distributed among field units. A function might be computer-automated, or it might entail extensive human intervention. Finally, a function might be specialized, or it might be an aspect of higher level functions.

Centralized Versus Distributed

Most ITS functions require communication of surveillance information from the field, assessment of the information, and execution of actions. In a centralized system, decision making (whether automated or not) is concentrated at a single location. As a consequence, communication requirements may be large whereas, on the positive side, scale-economies might be exploited. In addition, centralization distances the decision makers from the field (the consequence being a loss in familiarity with actual conditions). In a distributed system, decision making is localized, perhaps in lower level management centers or perhaps in fully automated field units.

Automation

Automation can free humans from the more tedious work, so they can focus on higher level decisions. Already, incident detection algorithms can free up operators' attention, and adaptive signal control can reduce the need for manual overrides. However, during abnormal situations, it may not be appropriate to rely on automatic responses. Computers might then serve as decision support tools rather than decision making tools. TMCs could activate, for instance, incident management procedures only after a human confirmation, or perhaps the human could actively direct the response procedures. The primary issue is then which types of ITS functions demand human involvement, which types would benefit from a combined computer/human approach, and which can be entirely automated.

Specialized Versus Encompassing TMCs

Most existing TMCs are geared toward performing two major functions: incident management and signal control, both of which entail various supporting functions (e.g., dispatching emergency vehicles or traffic surveillance). However, many of the proposed ITS functions do not fall neatly into the existing categories. AVI for automatic toll collection, for instance, conceivably might be integrated into general roadway surveillance and potentially even supplant it. Two distinct avenues for implementation are (1) to incorporate new functions within the functions served by existing TMCs, or (2) to create new TMCs that operate with some degree autonomy.

FOCUS GROUPS

The aim of the focus groups was to facilitate discussion among experts in TMC operations regarding organizational structure, functional assignment, and internal operations, as a way of documenting the strengths and weaknesses of the various alternatives. A total of four meetings were held, two in Northern California (at Caltrans District 4 headquarters) and two in Southern California (at Caltrans District 12 headquarters). In each location, a morning meeting concentrated on managerial issues and an afternoon meeting concentrated on technical issues.

Several weeks before the focus groups, invitees were mailed a copy of the PATH working paper on existing TMCs and a discussion paper on issues in TMC organization. The format of the meetings was discussed in the cover letter, and an agenda was provided. A total of 50 people attended the four meetings, some of whom attended multiple meetings.

The meetings began with introductions, a 10-minute review of existing TMCs, and a 10-minute presentation on TMC organizational issues (following the format of Section 3). At this point, the thrust shifted to discussion. In the managerial sessions, the discussion was divided into four blocks, centering on the following issues: (1) traffic signal control and coordination, (2) incident management, (3) automated vehicle identification, and (4) managerial reporting and control. Each topic was introduced by presenting a list of opportunities and concerns. The facilitator opened discussion to the group by requesting comments on institutional aspects of the technologies and the strengths and weaknesses of alternative organizational designs. The discussion was directed only to the extent needed to keep on topic and on schedule and to allow all participants opportunity to speak. The format for the technical sessions was similar, with the exception that managerial reporting and control were not included and participants were instructed to focus on technical issues, such as communication protocols and software requirements.

Findings

The findings are categorized according to major themes, which tended to be common among all focus group sessions.

Funding

Perhaps not surprisingly, there was a strong consensus among all four groups that carefully directed funding was essential to implementing ITS. Local agencies, especially small cities, lack both the budget and staff to implement existing technologies, and it seems unrealistic that these agencies would divert already tight funds to advanced technologies. Beyond the basic budget squeeze, there was a strong sentiment that state and federal funding should be used to leverage agencies toward better coordination, by targeting funds toward inter-jurisdictional projects. Comments in this regard were highly consistent with Booz-Allen & Hamilton's conclusion that "the political unit that controls the financial resources has the ability to shape how ATMS is provided."

On the contrary, many felt that funding would be more plentiful if the benefits of ITS were documented carefully. The FHWA Field Operational Test (FOT) program was identified as an important element of this effort. However, evaluation was also viewed as impor-

tant to non-FOT projects, and many felt that ITS systems should routinely generate data for evaluation purposes. As in the Booz-Allen & Hamilton study, rigorous cost-benefit analysis was strongly supported.

Maintainability

There was also a strong sentiment that more care should be given to ensuring the long-term maintenance of systems as they are implemented. Participants expressed strong concern that the systems being implemented today may have diminished effectiveness because they are difficult to maintain or because there is insufficient funding for maintenance. A solution would be to include maintenance cost as an explicit factor in system selection, along with redesigning systems if maintenance costs are prohibitive. In addition, a life-cycle budgeting approach was supported to ensure that future funding is sufficient for adequate maintenance.

Coordination

There was considerable discussion on the viability of leadership-based organizations, with no strong consensus. On one hand, many argued that no agency would yield "control" of their transportation system to another because of liability reasons or a desire to retain "ownership." As stated in the Booz-Allen & Hamilton study, "by agreeing to permit another entity to 'control' their infrastructure, they may believe that others will make decisions and take actions that may not be supported by their own constituents."

On the other hand, several examples were cited of cities that had successfully turned over control of traffic signals to other agencies without encountering major obstacles. Overall, there appeared to be agreement that adoption of leadership type organizations hinged on three critical factors: (1) funding incentives, (2) demonstrated benefits, and (3) coordination from a neutral agency, most likely a Metropolitan Planning Organization. These factors are needed to convince governing bodies to participate in such efforts. On the other hand, Booz-Allen & Hamilton's conclusion that "regional ownership is unlikely" also likely holds true, and that a more realistic scenario would be where each jurisdiction retains ownership but allows regional coordination under tightly prescribed conditions.

There appeared to be few obstacles to decentralized structures, so long as this was interpreted as simple information exchange without control. However, participants were skeptical that information exchange was sufficient to achieve coordination. Success would depend on the procedures enacted to respond to information, which would require careful study.

Overall, participants appeared to be less concerned about the type of organization structure than about ambiguity. For instance, participants saw fewer problems with an outside agency completely taking over operations than with an outside agency that might occasionally assume control (perhaps in response to an incident). Hence, there was a strong consensus that whatever organizational structure is implemented, roles and responsibilities must be defined precisely.

Conflict Resolution

Several participants commented that coordinated systems are difficult to implement because different agencies have different goals and objectives. For instance, some cities are quite supportive of projects to improve throughput on major arterials and to allow their use for diverted freeway traffic, whereas many are absolutely opposed. Support or opposition often can be traced to traffic impacts on residents and the significance of the traffic to the city's tax base; and because city councils respond to differing constituencies, they naturally have different objectives.

As one participant stated, "when the vision is common, the opportunities are there." There was a strong consensus that transportation agencies need to define such a vision and to establish processes for resolving conflicts when they arise.

Information Exchange

No one stated that major technical obstacles stand in the way of coordinating ITS systems. What is most needed is to define the interfaces. As a first step, high priority was given to developing interchange standards for signal plans. This might be followed by interface standards for other elements of the transportation system. In this regard, the TravInfo project was cited as an example for traveler information. There was a consensus, however, that standards should be devised by committees of experts through a consensus process and not legislated or imposed by higher level agencies.

Public Image

Participants were concerned that all projects be sufficiently well conceived to pass the test of public scrutiny. This meant that ITS applications should provide tangible benefits to individuals and should avoid traffic enforcement or other aspects of control. Public image was an especially large concern in AVI systems. There was a consensus that agencies should be totally open with the public about all possible uses for AVI information before deployment. Furthermore, many felt that AVI tags should only be used for limited purposes, such as toll collection. Broadening their use to traffic surveillance, vehicle inspection, etc., especially after the fact, was viewed as risky, because it engenders the "Big Brother" specter.

Management Reporting

There was a strong consensus that the success of ITS hinged on demonstrated cost-effectiveness. To this end, it was suggested that the State of California establish a "mobility index" that would be a common yardstick used in all regions to measure the performance of the transportation system on a daily, weekly, monthly, and annual basis. To this end, it was viewed as essential that new systems have built-in capabilities for archiving data so that these statistics could be generated automatically and that the State should develop standards for how these data are reported. This may result in a uniform management information system that enables access to a broad range of transportation statistics including delays, traffic volumes, transit usage, and accidents. This information could then be used for an array of purposes including staffing, safety improvements, and transportation planning.

Comments on Technologies

Participants also provided specific suggestions on the implications of ITS for signal systems, incident management and AVI.

Signal Systems

Considerable enthusiasm was expressed for using ITS to coordinate signals between adjacent jurisdictions and between arterials and ramp meters. The preferred approach was first to establish uniform protocols for exchanging information on signal plans and to coordinate responses through multi-jurisdiction signal committees. This was viewed as especially important in areas where Caltrans manages signals at diamond interchanges and along major arterials that pass through multiple jurisdictions and/or parallel major freeways. At the same time, participants recognized that these steps might be insufficient in the future with the deployment of adaptive signal systems.

Incident Management

Participants saw considerable opportunity for ITS in incident management including (1) closed-circuit-television (CCTV) for incident verification, (2) remote command centers to coordinate incident response, and (3) improved communication to, from, and at the scene through wireless technologies. The remote command center might be especially effective in dispatching hazardous materials crews, specialized maintenance equipment, or the coroner to the accident scene.

Automated Vehicle Identification (AVI)

Suggested applications of AVI included toll collection, air quality enforcement, mayday/safety devices, commercial vehicle inspections, and fleet management. Many participants were skeptical about the use of AVI for law enforcement purposes, whereas others felt this was viable.

The focus groups concluded with a discussion of ITS opportunities and obstacles. Opportunities included (1) faster and better information for travelers and TMC operators, which would enable better choices, (2) multi-agency and multi-modal coordination, and (3) creation of additional resources. Obstacles included (1) individual agencies that may not strive for the common good, (2) resistance to change and "turf" battles, (3) inability to maintain systems, (4) liability and privacy concerns, and (5) inability to fund deployment and operation.

DISCUSSION OF RESULTS

We have presented the vision of CIT, which is an integrated network of public and private organizations working toward a common mission of facilitating travel across all modes of transportation. ITSs serve as an enabling force for CIT, providing the technological capabilities for its fulfillment. Just as important, however, is how CIT fits within the institutional environment of state and local agencies. We have worked toward understanding how CIT and ITS can be implemented within the organizational framework of these agencies.

Throughout the study, we encountered considerable enthusiasm for ITS. Participants were nearly unanimous in their belief that ITS has improved their working relationships with other agencies and that one of the most important benefits of ITS was improved coordination. Although participants generally felt that a decentralized organizational structure was more practical within the current institutional environment, they felt that leadership-based structures might be viable in the future, provided that the benefits could be demonstrated.

There was also a strong commitment among state agencies and some local agencies toward implementing an array of ITS services. In most cases, participants felt that the ITS services should be assigned along the lines of current agency responsibilities. With respect to internal organization, the ultimate answer would depend on costs analyses and technical feasibility and not so much on institutional considerations.

Despite the enthusiasm for ITS, significant obstacles lie ahead. Participants were worried about the ability to fund and maintain ITS. They were worried that parochial interests might stand in the way of improved coordination. They were worried that some agencies were not sufficiently supportive of innovation and change. They were also concerned that the benefits of ITS might not be documented, which could stand in the way of future deployments.

Although the participants' focus was on the deployment of ITS, their comments also have relevance for the ITS research program. In some cases, this is not reflected so much in specific comments as in participants' priorities and attitudes, as expressed in focus group sessions. These are summarized below.

Time Frame

Nearly unanimously, participants were focused on short-range applications of ITS, mostly in the time frame of two years or less. For instance, participants showed considerable enthusiasm for, and detailed knowledge about, signal control systems and incident response strategies. On the other hand, medium-range applications such as AVI evoked much less discussion and interest.

Linking Information to Actions

Transportation management requires the coordinated effort of multiple agencies and multiple divisions within agencies. Unfortunately, it appears that some of these organizations suffer because the information is not being collected by the organization that is empowered to act on the information. This is most apparent in incident response strategies, where the focal points of transportation information, TMCs, have limited power in responding to incidents.

Broadcast Orientation

TMCs as they exist today disseminate information via broadcast technologies (changeable message signs, radio stations, etc.) and collect information in aggregate (mostly via loop detectors). ITS presents the opportunity for targeting information collection and dissemination to individual vehicles, drivers or travelers. AVI is one aspect of this opportunity. Other aspects include safety devices, in-vehicle signage and, eventually, automated highways. Evolution from a broadcast orientation to a "narrow-cast" orientation likely

will require significant changes in the function and organization of TMCs.

Embracing of New Technologies

Although all participants were enthusiastic toward ITS within the context of their current functions, there was some hesitation toward expanding their functions. Lack of funding was an obvious concern. Just as important, perhaps, was that some agencies are nervous that they will be perceived as invading someone else's "turf." Although this type of caution has helped create a cooperative spirit among agencies, it has also created an obstacle to innovations in how transportation is organized that ultimately may affect ITS implementation.

Organizational Boundaries and Performance Measures

There is a significant opportunity to use ITS systems for calculating transportation performance measures on an ongoing basis. These measures could be the basis for a performance-based incentive system, which could reward TMC personnel for their ability to respond to incidents and otherwise manage the transportation system. The measures further could be the basis for continuous improvement systems aimed at ongoing reduction in delay, accidents, and other impacts. To make such a program effective, further consideration is needed on organizational boundaries so that overlapping responsibilities across agencies and departments do not dilute TMC personnel's ability to manage the transportation system.

To conclude, the above four factors have profound implications for ITS implementation and research. Each demands careful deliberation at a strategic level and, possibly, changes in how transportation agencies are organized and how they relate to each other. From the research perspective, the greatest risk is that innovative ITS concepts may have no home for the following reasons: they are difficult to implement within existing organizations; there is no long-term plan for their incorporation and coordination; there is no one within operating agencies to advocate the concept; and agencies are not empowered to act on the information that they generate.

It should be pointed out that the organizational issues facing ITS are not unusual. Wilson (*9*) describes the importance governmental agencies place on autonomy. He states that by finding a unique functional niche, organizations avoid external competitors. In the process, however, they tend to avoid taking on new tasks that deviate from their traditional core responsibilities. As an example, he cites the Army's decision to develop a large helicopter fleet out of deference to an agreement with the Air Force that forbade purchase of fixed wing aircraft rather than to technical considerations favoring helicopters over alternatives. In ITS there are similar risks: that technological choice will be driven more by long-standing organizational functions than by what is best for the system.

To overcome these potential barriers, we believe that is it essential to reconsider the lines drawn between organizations, both within and between agencies, to determine whether they still make sense in the ITS environment. Further, it is essential to strengthen the dialogue between the researcher and practitioner communities, so that the two groups work together in developing a plan and a vision for computer-integrated transportation.

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