CONFERENCE I RESOURCE PAPER

Mainstreaming Management, Operations, and Intelligent Transportation Systems into the Planning Process

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The integration of intelligent transportation systems (ITS) and management and operations (M&O) into the institutionalized planning and programming process is an essential precondition for improving service. This paper attempts to incorporate the convergence of recent relevant experience and thinking from three sources. First, it includes the experience—through formal transportation system management (TSM) and congestion management systems (CMS) planning—with incorporating supply and demand management-based improvement projects (including ITS) into the conventional statewide or metropolitan planning and programming process and participants.

Second, this paper also reflects the more recent experience with ITS-deployment planning as a discrete systems engineering and integration activity that is conducted separately from the conventional planning and programming process by staff of facility-owner operations. Finally, it includes the emergence of a policy focus on systems M&O at the state and metropolitan level, with implications for not only planning and programming but also for the roles and relationships among stakeholders in the real-time service delivery that is implied.

The concept of M&O provides a distinct policy orientation—one that can stand alone or be combined with other policies and programs, such as highway capacity expansion. ITS is a principal programmatic means of pursuing this policy through the regionally integrated application of computation, communication, and control technologies.

The context for surface transportation has changed radically over the last 2 decades, whereas the conventions of transportation network services have hardly changed. There is an emerging confluence of 21st-century context features that reflects a new reality: a knowledge-based society places a high premium on information, efficiency, convenience, and responsive services.

ORGANIZING FRAMEWORK AND DEFINITIONS

Systems M&O can be defined in terms of policy and programmatic orientation as a deliberate policy focus on improved M&O of the existing infrastructure. A working definition is

> Maximizing performance of existing infrastructure in the provision of reliable, safe, and secure mobility under real-time conditions through regional deployment and integration of monitoring and information with customer-responsive systems operations and services.

This paper defines "operations" as real-time modifications to service features of existing facilities and "management" as activities that are oriented to improve user ability to capitalize on existing infrastructure.

Mainstreaming is defined to include the gradual development and organization in a logical, structured, open process of the complete range of policy and technical activities that are necessary to result in improved regional systems M&O. As described in the remainder of this report, the broad changes that are needed include

- Improvements to the existing "conventional" statewide and regional planning and programming process that focuses on performance,
- Establishment of regional ITS integration activities and resulting systems architecture as a part of an expanded cooperative planning process; and
- Incorporation of key aspects of ongoing operational planning and real-time system feedback into planning and programming.

Although it is not within the scope of this effort to invent a proposed new planning process, many of the key challenges that are emerging can be identified.

Role of ITS as a Conceptual, Physical, and Operational Framework to Facilitate M&O

The concept of M&O provides a distinct policy orientation—one that can stand alone or be combined with other policies and programs, such as highway-capacity expansion. ITS is a principal programmatic means of pursuing this policy through the regionally integrated application of computation, communication, and control technologies.

Conventions of ITS planning have identified a set of basic service components that are broken down into 30 specific user services and equipment combinations that deliver those services. The basic components cover the complete range of traffic and transit operations, traveler information and navigation, incident and emergency management and response, electronic toll and fare systems, vehicle-safety systems, and commercial vehicle-regulatory automation. The basic surveillance, control, analysis, and communications features of these services support a host of specific "market packages" for a complete range of related programs that are consistent with M&O, such as preferential treatment, telecommuting, smart cards, and pricing. Not all of these programs are infrastructure-related, but they still benefit from communications and information systems that might be developed as part of ITS.

The principal feature of M&O is the reliance on combinations of integrated strategies that are enabled by advancing technology to provide the maximum possible service with the framework of the existing facilities. In addition to improvements in efficiency and effectiveness of existing facilities, important new services and service functions are facilitated. The potential of operational integration on the basis of an "architecture" is introduced, which identifies the transportation systems functions, allocating them to subsystems and specifying how they are linked by communications with key data flows, interfaces, and institutional roles.

Thus, M&O is not the "same old traffic operations" and "too small to matter" (TSM) low-cost concepts. It adds not only new technology but also a conceptual, informational, and physical framework that supports a change in perspective and responsibilities of government for transportation services.

New M&O Imperative: Driving Forces and Characteristics

The context for surface transportation has change radically over the last 2 decades, whereas the conventions of transportation network services have hardly changed. There is an emerging confluence of 21st-century context features that reflects a new reality: a knowledge-based society places a high premium on information, efficiency, convenience, and responsive services.

Yet, the performance offered by the transportation infrastructure is too often characterized by chronic peak capacity imbalances, long-lasting incidents, lack of information about mode and system status, jurisdictional fragmentation, unavoidable intermodal friction, and manual regulatory administration. The logic of M&O and the focus of ITS are being shaped by these factors as well as by the following:

- *Growing and changing demands*—Urban areas are facing a 50 percent growth in travel over the next 20 years. Spreading peaks and new movement patterns for which the existing network was not designed emphasize the need to actively adjust the existing facilities to better respond to changing requirements.
- *New service attributes required*—The service orientation of the U.S. economy is generating customer expectations, both passenger and freight, for a broader range of performance and service options. These options include new information-based user-service requirements on the basis of M&O, including reliability, navigation, traveler information, security, crash-avoidance, and speed and capacity.
- *Constraints on traditional approaches*—The impacts of new facility construction, both high fiscal and environmental costs, often set practical limits on additions of new capacity. These limitations necessitate the most aggressive efforts to make the best use of available assets, placing a premium on an asset management perspective.

• *Growing impacts of disruptions*—The "unpredictable" disruptions caused by the high frequency of crash, breakdown, or weather-related incidents are now routine. These disruptions cause more than 50 percent of urban travel delay. Added to this is the continuing reconstruction and maintenance activities that are associated with the aging infrastructure. Indeed, over half of urban delay is caused by such incidents, which cannot be addressed other than through operational measures.

• *Increased customer responsiveness*—The effectiveness of conventional capital-intensive strategies is limited. Much of the service performance that is demanded of a just-in-time society cannot be addressed by new capacity alone. Networks that operate at higher capacity, with peaks, imbalances, incidents, and a mix of users with various appetites for improved performance, imply the need for (if not a market for) active system M&O.

• *Pressure on government for improved effectiveness*—The continued pressures of deficits, downsizing, devolutions, and deregulation have encouraged state and local governments, through major strategic planning efforts, to "reinvent" themselves and find ways for more effective service delivery, focusing more on outcomes and less on inputs and outputs.

• *Enlarged role of the private sector both as partner and independent service provider*—A public-sector commitment to operations can support major emerging private industry service initiatives that offer important user benefits, especially those associated with emerging in-vehicle systems, such as safety and information, or privately provided market services, or both. New private-sector information services also have the potential to substantially change how users view and use the system.

• *Introduction of information technology and systems engineering*—The introduction of new computation, communication, and control technology now provides the basis for ITS architectures that can support a wide range of user services on the basis of M&O features, as well as strategies in which integration and synergy are important.

These forces suggest changes in demand that include the desire for a new mix of services. Together with the obvious constraints on other ("build") options to better relate transportation supply with changing demand, these factors have resulted in the expansion of opportunities that are associated with evolving technology, which implies the potential for new services, processes, and relationships.

M&O Characteristics: Service, Policy, Programmatic, and Institutional

The driving forces suggest the need to evolve toward new service delivery objectives of the surface transportation infrastructure above and beyond the traditional focus of relying primarily on new capacity provision for maintaining or improving service.

The key service objectives of M&O, in response to the driving forces, would relate to increased focus on a customer-oriented, performance-based approach to transportation infrastructure service provision. These features, recognized in existing TSM and travel demand management (TDM) practice and engaged through the CMS process, have been further developed in the ITS planning to date. In service objective terms, these features include

- Using the existing infrastructure with greater efficiency
  - Minimizing efficient use of existing capacity through real-time facilities and systems control of flows and access
  - Increasing convenience and efficiency through automatic electronic tolling and billing for a wide range of facilities and services
- Minimizing service disruption from nonstandard conditions
  - Minimizing (50 percent) the delay due to incidents through active response to disruptions and emergencies
- Responding to demand for new service attributes
  - Operating systems to increase reliability and security (more important than speed)
  - Providing premium (speed limit) service priorities for certain customers or vehicle classes
- Maximizing informed customer travel choice
  - Empowering user choices through provision of general and personalized travel-condition information to promote informed user decisions about route, mode, time, conditions, and transit service
  - Reducing delay, circuitry, and increasing convenience by offering on-board navigation and yellow pages information
  - Incorporating market choice through electronic pricing and traveler information
  - Increasing levels of safety and security
  - Providing priority service for emergency vehicles through controlled preemption
  - Providing personal security through emergency-response dispatching
- Improving commercial efficiency and competitiveness
  - Improving intermodal services through operation integration
  - Increasing efficiency through commercial fleet dispatching and automated regulation.

These objectives accept the notion that although congestion cannot be eliminated, it can be managed, including the improvement of a series of attributes that can

make them more acceptable to users. A regional program that adopted these objectives as the priority for use of available resources would look very different from today's typical program.

Toward a New Service-Delivery "Model"

This service orientation implies profound changes in the service-delivery "model"—what services are delivered, as well as how, when, and by whom. In fact, M&O introduces a new orientation to the overall "enterprise" of infrastructure-based services.

A set of low-cost, spatially extensive, high-tech capital improvements must be implemented to facilitate M&O. This new ITS infrastructure of surveillance, communications, control devices, centers, and information dissemination must be staffed, operated, and maintained on a continuing basis. Important policy decisions about operational regimes and protocols must cooperatively be reached. Taken together, these responsibilities imply characteristic activities and strategies with important institutional implications for the responsibilities, resources, organization, staffing, and processes for service delivery at both the state and metropolitan levels.

These strategies include a new set of planning, deployment, and operations processes that are generally considered outside the scope of current capital facilities-oriented planning, programming, and deployment processes. Three features of M&O, as facilitated by ITS, differentiate an M&O-oriented service-delivery process from a conventional process:

- Impacts of customer and performance orientation,
- Role of performance and feedback—systems engineering, and
- Need for new forms of partnership.

Impact of Customer and Performance Orientation

The emphasis on service delivery—defined in terms of real-time performance monitoring—radically shifts the focus of provision from facilities to operations. This service orientation is reinforced by the convention of ITS engineering that builds functionalities around a disaggregation of user-service requirements with specific functionalities that are allocated to identified control and informational devices.

The customer emphasis reflects the fact that M&O can respond, with ITS "assists," to a wider range of desired service attributes that are based on operational activities, such as minimizing incident-related disruption for improved reliability, disseminating information on travel conditions, or providing emergency responses to real-time communications of individual vehicle problems (MayDay).

The implication of M&O, implicit in ITS-deployment conventions (and encouraged by its relatively low cost), is the provision of service at the relevant trip scale. ITS are defined on a functional instead of on a jurisdictional basis. A significant feature, therefore, is operational integration, which involves coordination across modes and jurisdictions through aggressive information sharing, operational cooperation, and joint service provision programs.

The customer (user) service function is also "provider neutral," that is, there is no technical assumption that the service provider is necessarily the infrastructure owner. In fact, the systems engineering as applied in ITS, with its discipline of "system, subsystem, and market packages," clarifies the opportunities for and technical interfaces to any potential service provider or cooperative arrangement.

Finally, ITS, with a strong focus on information, include both complementary and substitutable noninfraservice components in service delivery, such as travel information delivered in a variety of venues (especially in vehicles) and enhanced communication and information services as a substitute for some types of trip making (telecommuting).

Role of Performance and Feedback: Systems Engineering

The role of information, both as service and as infrastructure, is a key characteristic that ITS bring to M&O, impacting the system design and concept of how they should be operated. Central to advanced M&O is active real-time, condition-responsive systems operations, and management to maintain performance. Service outcomes therefore are dependent on adjusting operations and facility characteristics. This capability focuses attention on important service potentials that have not been central to conventional planning and programming. For example, half of urban traffic delay is due to nonrecurring incident disruption. Introduction of systematic incident detection, response, and management dramatically expands the target and potential of transportation service improvements.

Monitoring conditions and disseminating information have equivalent potential in other modes in terms of more closely aligning customer needs with operational realities through, for example, transit and parking information systems and intermodal coordination.

The monitoring and feedback potential of ITS also affects improvements, cycles, scales, and related costs. Many ITS services can benefit from ad hoc "tuning" and short-term modification to provide better service. The

institutionalization of a service provision style with incremental facility improvements, technology upgrades, geographic extensions, and synergism of mutually supportive functional capabilities characterizes contemporary M&O.

Need for New Forms of Partnership

The very nature of integrated regional operations implies a continuing responsibility of facility owners in new relationships with other facility owners who participate in a given (multijurisdictional) "system." These relationships with other service-providing stakeholders, both vertical and horizontal, extend to nonpublic works entities, such as law enforcement and emergency service providers who are crucial to several incident-response and safety-related services. Intensive cooperation, including collocation, common training, and protocols, is required on a multiagency basis. New cooperative roles also extend to multiregional and multistate relationships.

An organized programmatic focus on M&O implies not only changes in the existing planning and programming process for capital investments but also an extension into planning for operations and possibly into operations themselves. These changes also highlight the importance of owner-operator responsibility beyond construction of capital improvements, including nontraditional players. This suggests that relationships with a broader range of service providers, both public and private, will be essential.

The potential for partnerships extends to the private sector, both technologically and institutionally. Technologically, the information side of M&O must maintain design approaches in terms of systems and standards that are open and interoperable to private service providers. Future private-sector roles may include both in-vehicle-related services and the support of a private provision that includes a variety of traveler information, logistics, and security and amenity services—both free, custom-tailored, and consistent with the wide range of needs.

Institutionally, it is not too much to expect that in-vehicle information as a consumer convention (starting with MayDay, mapping, and yellow pages) will substantially alter how customer and users view the transportation system and may introduce new players and services into the travel services arena. The revenue market and expanded service opportunities that are associated with automobile personal computers and ubiquitous perfect travel-condition information could someday alter the role of sectors in M&O substantially.

A full understanding of the potential and implications of these features is still incomplete.

M&O in Conventional Planning and Programming to Date: Evolutionary Process

CMS Tradition

Traffic and transit operations are not new. The increased focus on M&O is part of an evolutionary process. It builds on the practice within the federal aid planning and programming conventions that are focused on efficiency-orientated, low-capital-cost, and noncapacity alternatives with minimum impacts. This tradition extends back to TOPICS (traffic operations to improve capacity and safety) and includes the TSM and TDM themes of the pre-Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) that were encouraged within the federal aid process.

Whereas TSM and TDM planning focused on levels of service and spot measurements and was generally highway-oriented and corridor-focused, CMS introduced a greater emphasis on multimodal performance, regular measurements, regional focus, and a broader array of integrated TSM and TDM strategies. The air quality constraints that were associated with the Transportation Management Area's (TMA) application of CMS also emphasized people, instead of vehicle, mobility strategies. (In these settings, "system" was defined as a process for developing strategies, not an operating construct.)

In this evolutionary context, CMS can be observed as a "bridging" experience that provides a valuable step toward greater operational focus on the part of the metropolitan planning organizations (MPOs). Their principal impact is the focus on a performance-based approach for identifying supply- or demand-related projects [for the Transportation Improvement Program (TIP)] that improve performance of the existing systems.

ITS Deployment Planning to Date

ITS, as a programmatic concept, evolved out of a recognition of the potential contribution of a more systematic application of new technology and systems concepts. The focus on an operational demonstration of new technology and the development of the logical framework for its systematic application preceded any widespread discussion of the implications of an M&O focused policy element on the part of federal, state, and local governments.

The early development plan (EDP) process was developed by the Federal Highway Administration (FHWA) as means to jump start ITS deployment by funding the development of initial ITS-deployment strategies in nearly 75 metropolitan areas. Although there was no

emphasis on changing state or regional policy, the ITS program in effect described M&O-oriented planning. The program also required a modest systems-integration process that was sufficient to provide the basis for some initial deployment of ITS-user services while accounting for legacy systems and establishing a strategy for potential future evolution.

With some exceptions, EDPs were led by state departments of transportation (DOTs) that focused on their network interests, with the processes taking place largely outside the established planning and programming process (enabled in part by their discretionary grant funding). However, MPOs often served as the "venue" or convenors of these efforts.

A standardized EDP process evolved according to FHWA guidelines as modified through experience in the field. As described in this section, the process was designed to accommodate initial implementations, with the minimum necessary connections to the existing planning and programming activities. As a one-time funded activity, it was assumed (usually correctly) that these plans would be used as points of departure for incorporating a regional ITS-focused planning and deployment process into the local institutional framework.

It is important to note that although most EDPs were focused on start-up ITS deployments at the metropolitan regional level, states have also begun to evolve parallel processes. Whereas these state-level processes are at an appropriately higher level of generality, attempts are underway to integrate these processes with regional level efforts within the state jurisdiction.

The EDP conventions include important features that, in the long term, must be part of the mainstreaming effort, including both a planning component and systems integration and operations planning component. The major steps in EDP planning are

- Define problems and needs in terms of measurable service outcomes. This activity is presumed to link directly to the established regional policy and to account for exiting conditions and systems in place.
- Develop a consensus-building process and a commitment to cooperative roles. An expanded stakeholder group should include those additional parties that are necessary to M&O but are normally outside the planning process.
- Develop a mission and vision of how ITS can support the needs of specific users, including an initial cut at defining the specific priority user services.
- Develop a concept plan of how specific ITS elements (market packages of strategy components that deliver services) would be deployed to produce the desired services.
- Develop a regional systems integration strategy. This component includes a high-level systems description with subsystems and enough information about functional requirements to develop an initial "layered architecture," including transportation components, communications, and institutional responsibility.
- Develop operations and implementation strategies, including the approaches to deployment, operations, and maintenance, with associated institutional and financial arrangements.

Two principal weaknesses of the EDP process, which are being corrected in continuing efforts, were time and budget restrictions and the lack of familiarity of many participants with ITS technologies, cooperating concepts, and systems engineering approaches.

First, regional integration frameworks were often developed at the conceptual level, without details on subsystems and information flows or full logical and physical architectures. Subsequent studies and interaction with the model, provided by the National Architecture Effort, has led to a more disaggregated approach that is necessary to move to engineering-level decisions.

Second, lack of integration with the planning process, especially ongoing CMS efforts, hampered follow-on. EDPs typically recognized the need for these connections but, within their time frames, lack the opportunity to get in cycle with the MPO planning process for more rigorous relationships. Furthermore, such relationships have awaited a clearer expression of policy, especially regarding priority and resources from state DOTs and other MPO members within the TIP framework.

Beyond EDPs: Continuing ITS Planning

Systems integration and operational planning for ITS deployment continues as a discrete (semi-independent?) operation, with its own internal requirements. These efforts, principally state DOT-led, exhibit tremendous variation, from a focus on specific project deployment and actual operations to further development of regional service policy and regional integration apparatus.

In most metropolitan areas, the development of integrated regional ITS plans and operational planning to date has been "partial" and has focused on ad hoc ways of adding improvements to legacy systems, with the minimum necessary comprehensive system (architecture) development. In addition to their project-deployment focus, a few efforts have continued regional systems-integration activities as a necessary precondition to respond to the requirements or opportunities for legacy integration, interoperability, efficiency, and so forth.

To date, the ongoing ITS planning and deployment activities have had little impact on the plans and programs within the "conventional" process. Systems integration and operational planning are generally developed outside the planning process. The effort typically has been state-led and focused on state-owned facilities or projects of state interest, such as metropolitan or statewide traveler information. States have developed the necessary bilateral relationships with local governments and with participants of other nonpublic works (such as state highway patrol). To some degree, this reflects the lead times that are necessary to interest the majority of MPO members and to initiate a consideration of the issues of M&O within the multiyear cycle of MPO policy and plan development. It also reflects the fact that the funds being used have not typically been those controlled by MPO consensus and that the funds have not competed on a major scale with other agreed-on MPO priorities.

As they become more comprehensive, the overlaps with regional planning and programming will become more obvious, and stronger interconnections—if not integration—will be necessary. However, it is important to preserve the features of ITS planning that serve to promote the importance of M&O. Steps to preserve these features include

- Highlight the potential of specific services and functions at the operational level.
- Establish long-range comprehensive frameworks and standards for statewide integration and interoperability, to name a few.
- Communicate ITS (and M&O) potential through the rest of the policy and planning process.
- Draw attention to resource and institutional issues.
- Consider the tremendous variation among states and metropolitan areas regarding the state of fully integrated systems framework.
- Remember federal aid rules—both architecture and systems integration will push for fuller application of more systematic approaches.

Mainstreaming Challenges

Mainstreaming could be defined at many levels, from the existing modest role of CMS within the conventional planning process in TMAs to a higher level that involves the gradual development and organization in a logical, structured, and open process. This process includes the complete range of policy and technical activities that are necessary to improve regional systems' M&O. Such complete integration must meet a broad range of policy, institutional, technical, and resource challenges, many of which are summarized in Table 1.

This discussion does not cover the complete range of activities that are associated with M&O service delivery; in fact, no commonly accepted overall framework exists that would incorporate all the steps from policy development to real-time operations (such as adjustment of a traffic-control device). This paper discusses the implications of an increasing M&O orientation on those activities that are within the conventional scope of planning and programming, and how they may evolve as part of the larger framework. Current experience is used to identify some of the critical challenges that planning and programming, whether formal or informal or whether within the current institutionalized process or outside, must initially meet to move this process forward.

Current thinking about M&O and ITS is still in a pioneering phase. Responsible institutions are reinventing the planning and programming process as they proceed, in some cases formally, but in most cases, by informal actions and relationships around the margin of their regular institutionalized responsibilities. The overarching issue is the degree to which planning and programming are likely to be substantially transformed as they become increasingly responsive to real-time delivery of service as distinct from the long-term provision of service-supporting infrastructure.

Contexts: Basic Scales and Activities

Although the range of issues that are related to mainstreaming varies by context, there are certain common crosscutting challenges that are suggested by the experience to date. These challenges are discussed in the remainder of this section and are listed as follows:

- Policy understanding and support for M&O,
- ITS strategy and program development,
- Systems integration and operations planning,
- Necessary technical tools and data,
- Expanded cooperative context,
- New resource-allocation requirements, and
- Process implications.

Mainstreaming must be achieved in five separate contexts in which resource allocation or design decisions are being made that critically affect what services are offered and how they are achieved. These five contexts include

- *Statewide and regional planning and programming*—existing statewide regional planning and programming process (as generally defined by federal guidelines) at the level of the statewide long-range plan and the State Transportation Improvement Program (STIP), as well as at the level of the regional long-range

TABLE 1 Traditional Planning Process Versus Management, Operations, and ITS

	Traditional	*ITS/Operations*
Orientation	Major capital facility (build/preserve) "Build" New capacity/service expansion Solving recurrent or "average" conditions Aimed at capacity, LOS, and safety	Systems operations & service provision "Do" Operations & efficient management of existing system Response to variation in conditions Solves different problems reliability, security, incident response
Temporal	Problems of tomorrow Forecast driven Long-term, multi-year implementation One-time decisions Static once in place Fixed, predictable technology and characteristics	Problems of today Response to current conditions Short-term, immediate implementation Continuous, incremental System evolves through feedback Rapidly changing technology and characteristics
Costs/Funding	Medium/high major capital facility Low/medium M&O Federal aid context and requirements	Low/medium capital/infrastructure Major life cycle operations costs Often implemented using local funds
Implementers	Public agency Construction industry, real estate, current users	Public and private partnership High-tech industry, small current constituency
Other Attributes	Stand-alone Separable Facility-based Low/medium technology Capital, service improvements Major construction Visible and permanent	Piggyback on other projects Connected through communications System-based, core central systems Advanced technology Non-capital (protocols, algorithms, communications) Minor or no construction Often hard to see

SOURCE: NCHRP 8-35, Mitretek, and Parsons Brinckerhoff

plan and the regional transportation improvement plan (TIP).

• *Corridor and project planning*—focusing on an analysis of corridor and subarea levels of alternatives that involve environmental analysis and preliminary design activities, as per major investment study (MIS) practice. However, this guidance does not address key issues that are related to integration of ITS into these processes.

• *Regional system integration and operational planning*—focusing on establishment of regional architecture systems integration. There is an initial effort that is required for initial ITS deployments; the process can be continued to an appropriate level of completion as deployment proceeds. Federal guidance for this process is under development, with a strong emphasis on relationships with other parts of the planning process.

• *Project development*—including not only conventional design activities but also, in the case of ITS projects, the involvement of key stakeholder operators in operations planning and systems analysis to ensure architectural consistency with related projects and for integrated follow-on.

• *Project and systems operations*—conventionally a voluntary, consensual, and ad hoc facility-owner-based activity that is undertaken as part of actual real-time facility and systems operations by specific operation staff.

These issues and those described in the following subsection must be considered at each level of planning in recognition of the time gaps and the often-tenuous relationships between higher-level and lower-level planning activities.

Policy Understanding and Support for M&O

The initial barriers to the integration of M&O and ITS into the existing planning and programming process is a general appreciation of the benefits of M&O on the

part of elected decision makers and management, including an understanding of ITS as the conceptual and infrastructure "bridge" to actual systems operations.

Concept Familiarization

The idea of M&O, on the basis of a user-services delivery system that is integrated regionally through a series of communications, analytical, and control systems and that involves the real-time cooperation of a series of service providers, is a new model of service delivery from the current mainstream. Education and familiarization are essential at two levels. First, the transportation decision-making and management levels of state and local governments must be convinced of the virtues of M&O (and therefore ITS). Second, the technical community must become familiar and comfortable with the concepts to understand and develop a systematic implementation process. Familiarization can be accomplished through technical documentation, demonstrations, and scan tours, to name a few. The EDP process fostered the use of visioning as an effective means of conveying the potential of ITS to potential constituencies that were not familiar with ITS concepts and their applicability.

Jargon

Jargon itself (as this paper demonstrates) is a barrier to broader understanding.

Scale of Benefits

A precondition to widespread understanding and acceptance may also be overcoming the "why bother?" phenomenon. Although the benefits of M&O and ITS, in general, are intuitively obvious, competition for resources and the planning process require quantification of impacts, benefits, and cost effectiveness. A special challenge to be faced in this regard is that although the cost effectiveness of ITS is typically quite high, the visible impacts are typically subtle and often depend on widespread level of implementation.

At the same time, as an increasing number of nonmobility program objectives have been formally incorporated into the planning process (and attracted their own constituencies), there has been a general professional unwillingness to use rigorous measures of the relative short-term measurable transportation benefits of alternative investments. Jump start projects, such as those undertaken through the federally sponsored model-deployment initiative, can demonstrate highly visible payoffs.

Constituencies

The focus of state and local investment in transportation improvements responds to an aggregation of stakeholder views about what is desirable and effective according to professional judgment and norms, industry and political interests, public values, and expectations. Each type of transportation improvement has its champions, whether it is highway expansion, light rail, or high-occupancy vehicle (HOV) lanes. Without such a constituency it is unlikely that major shifts in policy and resource allocation will take place. In this regard ITS have obvious handicaps and advantages. On one hand, they participates in the enthusiasm for new technology. The transportation professional community, over time, will undoubtedly become increasingly supportive as the promise of the concepts is realized in deployment. On the other hand, ITS lack the scale of capital investment that in itself attracts support because of direct (construction) or indirect (real estate) impacts. The lack of major ribbon-cutting opportunities (except for transportation management centers) is a handicap in this regard.

Promotion

ITS, within an M&O policy framework, must be promoted. Within the planning and programming process, institutional support can be very influential. Senior-agency leadership has already played a key role. Federal policies, through funded demonstrations and guidance, are obviously influential within the institutionalized planning community. State DOT leadership is also a consistent primary factor in the progress made by bellwether regions in ITS implementations. In a few cases, local leadership has emerged, recognizing the need for interjurisdictional cooperation to deal with local problems despite resource constraints. A remaining challenge is to support existing champions (who are often one-person bands) and nurture additional champions.

The existing committee structure within the planning community can be an important resource. Some regions and states have established ITS committees with expanded membership, bringing in other service-delivery stakeholders (such as law enforcement and emergency services). A few states have also undertaken ad hoc efforts to engage private-sector entities—users, technology vendors, and service providers—who are knowledgeable and interested parties regarding the promise of M&O.

ITS Strategy and Program Development

A key step in mainstreaming is an emphasis on M&O, which must be accorded an appropriate level of priority

in both statewide and metropolitan planning and programs. At present, individual ITS projects are being implemented but not as part of the mainstream. This results from the range of special demonstrations, dedicated federal aid programs, active interest by a division of state DOTs or specific local government support, or special MPO policy, to name a few.

Several Contexts

Mainstreaming M&O as a policy and ITS as a program is likely to evolve from both top-down and bottom-up influences. The challenge is to seek the appropriate approach at several levels. At the state level, a commitment to increased intensity of operations and introduction of new forms of transportation management must flow in part from a policy conviction. At the regional level at which projects are visible, a commitment to management must be understood in terms of specific project implications as well.

Strategic Outcomes

From the top down, the increased recourse to formal strategic planning within state DOTs in recent years has led to a more careful statement of basic policy objectives as the basis for the top element of a department's strategic planning activity. An "outcome" focus has placed greater emphasis on customers' definitions of desirable performance. Nonetheless, communication with customer perspectives, both private and commercial, by using surveys or other techniques with regard to refined program objectives remains tenuous.

At the same time, the pressure of resource constraints has continued the push toward efficiency and an increased general focus on preservation and operations program elements. In addition, federal policy has encouraged strategies that emphasize efficient systems management. ISTEA and the Transportation Equity Act for the 21st Century (TEA-21) include factors that support increased focus on improved M&O on an integrated basis at the appropriate scale. These factors include

- Competitiveness, productivity, and efficiency;
- Safety and security;
- Environment, energy conservation, and quality of life;
- Integration and connectivity;
- Operations;
- Preservation of existing systems;
- Coordination across boundaries; and
- Freight and transit stakeholders.

These factors establish a positive environment for the development of an M&O-related policy.

Performance Orientation

The key focus of mainstreaming is to ensure that the benefits of M&O are fully incorporated into the service provision and resource-allocation decisions and that the broadest range of customer-relevant strategies is considered. The real-time service focus on M&O responds to a high premium on maximizing system performance. A strong role for M&O within state policy is likely, therefore, to depend substantially on the orientation of the state plan and policy to link its achievements to performance (as distinct from physical measures of infrastructure output or conditions). As an increasing number of states adopt strategic approaches, it can be expected that operational performance will become an explicit element in statewide planning.

A key step in the logic of performance is the use of deficiency analysis, with performance measured against the objectives, standards, or measures of effectiveness, which state DOTs may wish to establish for each of their principal policy goals or objectives, or both. The linkage of policy goals with measurable standards for various operations services represents a powerful leverage, because M&O-oriented investments will often, although not always, be part of the most cost-effective approach.

In a few instances, statewide policies refer explicitly to improving the M&O of existing systems and the role of technology and ITS concepts. But few states have put into operation such policies in plans and programs.

ITS Program Elements

A key feature of the ITS approach to M&O is that it suggests a method to generate an overall M&O program. The concept behind such a program is that systematic, regionwide, and multiservice ITS deployment generates synergistic benefits that are not captured by piecemeal projects. For example, the addition of arterial traffic control integrated with freeway operations substantially enhances each. Full mainstreaming of ITS implies this type of programming.

There are a variety of mechanisms to generate service-specific ITS programs. The conventions of user service and user-service bundles, or core services, offer another mechanism for identifying the types of programs that might be implied by an M&O policy (such as freeway and arterial management, traveler information, and emergency vehicle preemption). If a regional or statewide ITS strategic plan or EDP has already been

created, the overall architecture framework that identifies the broad range of potential user services represents a resource from which the next logical phases of M&O investment can be drawn.

This type of thinking can also be extended to sections of state corridor planning in which generic appropriate strategies can be identified, the details of which are appropriately worked out within lower-level planning efforts.

From the bottom up, early deployment of ITS projects has, in some cases, provided sufficient visibility (i.e., demonstrable success, or staff support, to "gain a place" in state-level policy. There are additional roles for the same ITS technology and integrated systems as part of other programs for increased effectiveness of conventional improvements, such as ramp metering, as well as "stand alone" ITS-service programs (MayDay).

An M&O focus at the policy and program level also provides an opportunity to include nonconventional demand management strategies that have typically received ad hoc treatment. Value pricing and telecommuting provide two examples of non-infrastructure-related strategies, the implication of which is not yet visible, with strong ties to other components of comprehensive ITS programs through their dependency on real-time traffic monitoring and related functionalities.

ITS architectural concepts also suggest ways in which ITS and technology can benefit other state-level programs, such as safety, maintenance, and regulation. For example, the communications network that is used for traffic control may also be viable for maintenance operations.

Corridor-Specific Projects

At the corridor and subarea level, the challenge in mainstreaming shifts from the strategic to the tactical—the appropriate M&O treatment—which is consistent with regional policy. Corridor and subarea studies are typically occasioned by proposed major investments. Typically, ITS improvements have been afterthoughts, whereas major improvements were under consideration. However, the value of ITS in this context flows from three potentials:

- ITS improvements may permit a reduced scale or enhanced effectiveness of capital alternatives by virtue of operational features.
- ITS, in some cases, may represent cost-effective, stand-alone alternatives for the first phase in corridor-improvement strategies.
- ITS components may offer additional service features that are not presented by conventional capital alternatives.

Slating Projects

Whereas ITS may be part of the operations program emphasis at the state level, a crucial step in mainstreaming M&O at the regional level is the appropriate inclusion of ITS projects in the TIP. The source of such projects may be an ongoing regional ITS integration study or other ITS strategic activities, a specific corridor-related project, or the product of a systematic TIP candidate project evaluation.

The completion of a regional integration strategy can serve as a useful source for corridor-level M&O improvements that are consistent with a broader regional framework. A key feature on this scale is explicit analysis and comparisons among alternatives (as per MIS), with a strong emphasis on cost effectiveness and impacts (often air quality constraints).

TIP projects, in a financially constrained environment, are typically subject to some kind of evaluation process by using common criteria. Such criteria typically include

- Cost,
- Urgency,
- Impact on level of service or congestion,
- Air quality impact, and
- Support of land use.

Scoring methods are frequently weighted for noncapacity improvements or projects with an efficiency impact. An important aspect of mainstreaming is to develop criteria that respond to the unique features of M&O improvements, such as their short-term, cost-effective implementation and their ability to respond to nonstandard conditions.

Systems Integration and Operations Planning

Characteristics of ITS, including the use of remote, real-time conditions monitoring, automated analysis, data communications, feedback-based control algorithms, cross-system integration, and other features of advanced transportation and communication technology, require the introduction of systems engineering concepts and disciplines to the transportation planning, design, and operations processes. The importance of achieving interoperability for policy, efficiency, and market reasons requires explicit systems integration efforts. These efforts include an analysis of both legacy and future program development to establish a framework that minimizes the chances of major system, service, or geographic incompatibility, or technology-acquisition inefficiencies. FHWA has placed special emphasis on ensuring

interoperability by requiring systems integration efforts.

Systems integration studies are a form of planning and engineering that focuses on the technical demands that regional interoperability places on information-based systems if efficient systems operations and cost-effective development are to be achieved. Systems engineering as a discipline has a well-defined set of rigorous procedures for developing and designing customer-oriented, functionally defined, and information-based systems (with major software, hardware, and communications elements). An important product of such an effort is an architecture that documents key functions, relationships, and processes and that interfaces at the logical, physical, technical, and institutional levels. For ITS applications, much of this has been prepackaged in the form of a federally sponsored prototype called the "national architecture," which can provide useful examples and guidance to ensure more efficient development of each specific custom-tailored regional architecture.

There are, however, a range of important points of contact between systems integration studies and both statewide and regional planning. These elements include the need to cover a broad range of services (some of which may not be within the planning process) and the involvement of the complete range of potential stakeholders, some of whom are outside the traditions of the planning and programming process.

To date, regional systems integration has been partial, ad hoc, and state-led, sometimes with strong participation from affected local governments. (In a few instances, MPOs have played the role of convenors and organizers.) Indeed, as a "start up," it may be preferable to construct a special ITS strategic plan to generate an increased focus on the unique characteristics of and potential for ITS, as well as on the appropriate level of detail. These measures can build off the existing EDPs and add elements that have often been missing, including geographic and service coverage, a more complete regional systems integration framework (architecture), and a complete range of stakeholders. Features that can be more easily included within a stand-alone study include

- More comprehensive analysis of a complete range of user services and a more concrete definition of projects (as distinct from general concepts);
- Clear description of the regional systems framework and related investments that are implied;
- Opportunities to identify the benefits more widely to build an understanding of M&O; and
- Identification of necessary internal and external legal and administrative arraignments that include agreements with other necessary "partners," both public and private.

Planning for M&O, by definition, does not end with design and deployment. Given the built-in monitoring and feedback character of ITS-based M&O improvements, there are opportunities for minor improvements in operational regimes on a regular basis. Many ITS systems have, by their nature, the ability to make adjustments in their operations or upgrades in hardware or software in relatively short-time cycles, often at relatively low cost. Therefore, a logical follow-on to systems integration studies and deployment of any specific user-service-oriented system is the continuing cycle of upgrades and modifications. Decisions must be made about the nature of these improvements, which often involve renegotiations of protocols that are agreed on by participating state and local government owners and operators. This operational planning, therefore, takes place continuously "below the planning horizon" and is conducted not by planners but by operations personnel of the affected jurisdictions in various cooperative groupings.

Necessary Technical Tools and Data

If M&O-based programs and projects are to compete in the planning and programming process, they must be represented in the technical procedures in such a way that their inherent features and advantages are accounted for. Several mainstreaming activities, such as plan-strategy development, program slating, and alternatives evaluation, require that the costs, impacts, and benefits of ITS options be compared with other options.

However, the conventional alternatives definition, forecasting, impact evaluation, and costing procedures have been developed with terms and methods that are appropriate to long-lived, fixed, capital-intensive, and environmentally intrusive projects that have long lead times and in which travel behavior is forecasted. The very different characteristics of M&O strategies and ITS improvements indicate that a level playing field will require significant adjustments in these processes and supporting technical tools. These adjustments must account for

- Regional or area coverage (versus corridor),
- Incorporation of incident-delay reduction,
- Improvements in level-of-service reliability and safety (as well as delay),
- Value of enhanced traveler information,
- Life cycle M&O costs,
- Zero negative impacts,
- "Tunability,"
- Short-term payoffs, and
- Synergism with "off-site" improvements.

At present, data, codified experience, and analytical methods do not support an even-handed comparison of capacity versus operating-oriented alternatives, although current development of federally sponsored methods is making important progress. Critical needs include

- Codified costs and benefits data for a range of ITS improvements and applications;
- First-cut set of agreed-on evaluation criteria (measures of effectiveness) that reflect the targets, impacts, time scales, and geographic scale of ITS applications that are different from conventional improvements;
- General rules on the order of magnitude for travel behavior impacts of the broad range of ITS services, including guestimates on future synergism among services at widespread levels of deployment; and
- Behavioral-based simulation techniques that are also based on validated assumptions for network-based alternatives in terms of first-generation sketch-planning techniques that are easy to use

Capitalizing on ITS Data

ITS-related detection systems are already beginning to generate vast amounts of data on traffic patterns, including data on traffic response to varying conditions, both standard and nonstandard. Although the potential of these data has been much discussed, little systematic effort has been undertaken to organize the "archived data" function of ITS. Some metropolitan areas are now reaching the point at which detection coverage on the upper-level network is sufficient to justify the effort that is involved in developing quality control, sampling, and storage protocols for use in planning and evaluation.

The value of the data in the planning process covers the following functions:

- Developing and validating travel-demand models on the basis of the full variation of traffic conditions instead of a single average;
- Researching and developing new model structures on the basis of the ability to more accurately relate behavior to actual conditions;
- Providing systems performance data;
- Developing and analyzing plans; and
- Regulating development of special vehicle operations.

The value of ITS-derived data is likely to be related to the data's ability to provide the information currently missing from databases that is used to forecast, analyze, or evaluate. This formation includes substantial improvements in geographic coverage, duration, sensitivity to vehicle type, incorporation of variability, and relationships of recurring or nonrecurring causes and conditions. Those individuals who mainstream ITS-generating data into the planning process will have to grapple with a series of problems. These include responsibility and cost of archiving and analyzing data; interactions between planners and operators to improve quality control; and technical challenges of editing, data-quality control, data management, and access.

In addition, the transition from a data-starved, antiquated environment to a rich and recent-data environment will require a fundamental reassessment of the relationship between the "cost and value of knowing."

Expanded Cooperative Context

A key feature of ITS is the implication of the broad range of services and the integrated regional approach on the need for new cooperative relationships, both vertical and horizontal, among potential service providers.

Vertical cooperation among state and local governments and regional agencies has always characterized regional planning and programming, and in some instances, actual service provision (transit authorities). The concept of integrated operations emphasizes vertical interdependence. Much of the promise of advanced traffic management, for example, depends on integrated freeway-arterial operations, which require close cooperation between state DOTs and local governments.

Horizontal cooperation refers to the need for transportation agencies and other transportation-related service providers, such as law enforcement and emergency services, to move toward closer cooperation. The existing degree of independence and differences in motives can place an absolute cap on the ability to improve certain key transportation services. At the same time, improved joint response to roadway incidents and the opportunity to share information and communications infrastructure provide motives for collocation, joint program development, and shared policies among transportation and nontransportation agencies, all of which may have on-system responsibilities. Closer relationships at the operating level have been developing in several locations, but the opportunities associated with ITS infrastructure and the development of more formal comprehensive programs suggest the value of formalizing some of these relationships as a more stable basis for planning and investment.

Questions have been raised about the need for new institutional arrangements among multimodal transportation management ("metropolitan operating authorities" is a multimodal version of transit authorities), which might also formally involve nonpublic works agencies. There are a few such multijurisdic-

tional entities with operational responsibilities, such as TranStar and TRANSCOM. However, control of facilities and budgets will not be lightly loosened, and it can be expected that jurisdictions will move very carefully and slowly down the vector from cooperation to formal consolidation. Furthermore, the evolution of technology suggests the possibility that close operational integration can take place on a carefully targeted basis from distributed locations and with the aid of new communications and improved display systems, combined with automated analytical routines and predefined protocols. The future "metropolitan management institution" may indeed be a set of overlapping, virtual, bilateral, or multijurisdictional entities.

New relationships with private-sector players, who act as providers of services for ITS infrastructure on a commercial basis, are also needed. There is already a range of experience with informal relationships between private service providers and various state and local transportation agencies, particularly in the traveler information and incident-response areas. Formal contractual arrangements, both public and private partnerships, become important when there is a commingling or sharing of valuable resources, as in the bartering of public right-of-way in return for the private provision of communications capacity. As quality of information continues to improve and dissemination technology advances, the opportunities to turn more and more aspects of M&O into a "business" will increase.

Major barriers to more aggressive partnering are the administrative barriers that require major efforts when creating each new partnership, along with the general cultural divide of sectorial values and objectives, which must be overcome in each public or private partnership arrangement. Mainstreaming partnerships, therefore, will involve not only standardizing partnership arrangements but also a learning process (on both sides) of the values and objectives of each partner.

Such partnership arrangements will become increasingly important as the development of ITS spreads, and the resources that are represented become more commercially valuable. The private market for in-vehicle and personal communications devices is forecast to substantially outweigh the total public investment in ITS-related infrastructure. If the market for automobile personal computers and for personal transportation-related information services develops as anticipated, it can be expected that private-sector entities will take on new roles in the M&O arena. For example, non-intrusive vehicle-detection technology, such as the technology being developed to meet the Federal Communications Commission's cellular 911 geolocation requirements, could result in private entities becoming the principal suppliers of traffic information. Given the central role played by detection within ITS, it is not too great a leap to imagine major private entities replacing public agency roles as ITS service operators.

Promote New Resource Allocations

The end of an earmarked ITS program that was introduced by TEA-21 marks the passing of the "honeymoon period" in which ITS projects did not have to compete for resources and adds a compelling dimension to mainstreaming. ITS projects will have to compete for capital funds with other projects, as discussed earlier. M&O also introduces the need to account for the costs (e.g., maintenance and staff costs) for continuing service provisions. Therefore, resources for deployment of ITS systems that support M&O, as well as funds associated with service delivery, need to be separately identified in STIPs and TIPs.

The use of ITS as an "add-on" to conventional alternatives (e.g., new highway capacity within the context of an MIS) introduces the need to include M&O-related costs on a continuing life-cycle basis.

However, some of the most critical resources may not appear in STIPs. M&O programs introduce the need for additional operations personnel. This need has typically been a key constraint in the development of ITS programs. Because ITS projects evolve and may be too small to merit proper naming, a program-level budget is a logical approach.

In addition to departmental resources, attention must be given to the coordination and promotion of programs with related state and other public agencies, such as law enforcement, whose capacities are important for effective M&O. Most staffs from state DOTs have yet to reflect the substantial personnel time that should be devoted to developing the new arrangements on an interjurisdictional level that are required for cooperative systems operations to develop new public and private partnerships.

The competition for state and local funds for ITS, especially for operating resources, suggests that an aggressive effort should be made to open opportunities for private-sector investment. These efforts should be used not only when user-fee revenues are available but also to tap outsourcing opportunities in which private management efficiency and experience may reduce overall costs. Resources are also needed for the development of regional integration and basic ITS infrastructure as a stand-alone activity, as well as for service-oriented projects themselves.

Process Implications

This discussion suggests that M&O cannot play an essential role in the planning and programming process

without substantially affecting the existing policy process, conventions, methods relationships, and resource-allocation priorities. If the institutionalized process appears unable to support improved operations, as well as development and deployment of ITS, then the supporters of ITS, including state DOTs, operations-oriented units within state DOTs, interested local governments, and other public agency and private stakeholders in M&O and ITS, will continue to "work around" the process. M&O planning and deployment and operational planning would continue, and resources would be allocated in a separate process that would suggest suboptimal use of public resources and major opportunity costs in improving service. This places a burden on state planning entities and MPOs (and USDOT), as advocates of 3-C planning, to work with their constituencies toward effective accommodation and support of M&O.

A more desirable scenario is the gradual mainstreaming of M&O into the planning and programming process by "blending" the activities. In other words, the key aspects of the current conventions of statewide and metropolitan planning and programming would be integrated with principal features of systems integration and operations. This blending is based on the assumptions that

- A new orientation toward service delivery and performance feedback becomes a central feature of planning.
- The existing planning and programming process provides the necessary resource priority.
- Planning and programming institutions provide a positive technical setting for M&O strategies.
- Operations proceed at an integrated regional scale.

Figure 1 suggests the point of departure for such integration. The important role of operational monitoring and feedback is shown, with the potential linkage to needs assessment within the planning process. In addition, use of the user-service approach for mapping out a comprehensive ITS program in support of M&O is indicated relative to long-range and subarea planning activities. Figure 1 also illustrates the budgetary impact of continuing operations. Even though regional systems integration is shown as a somewhat separate process,

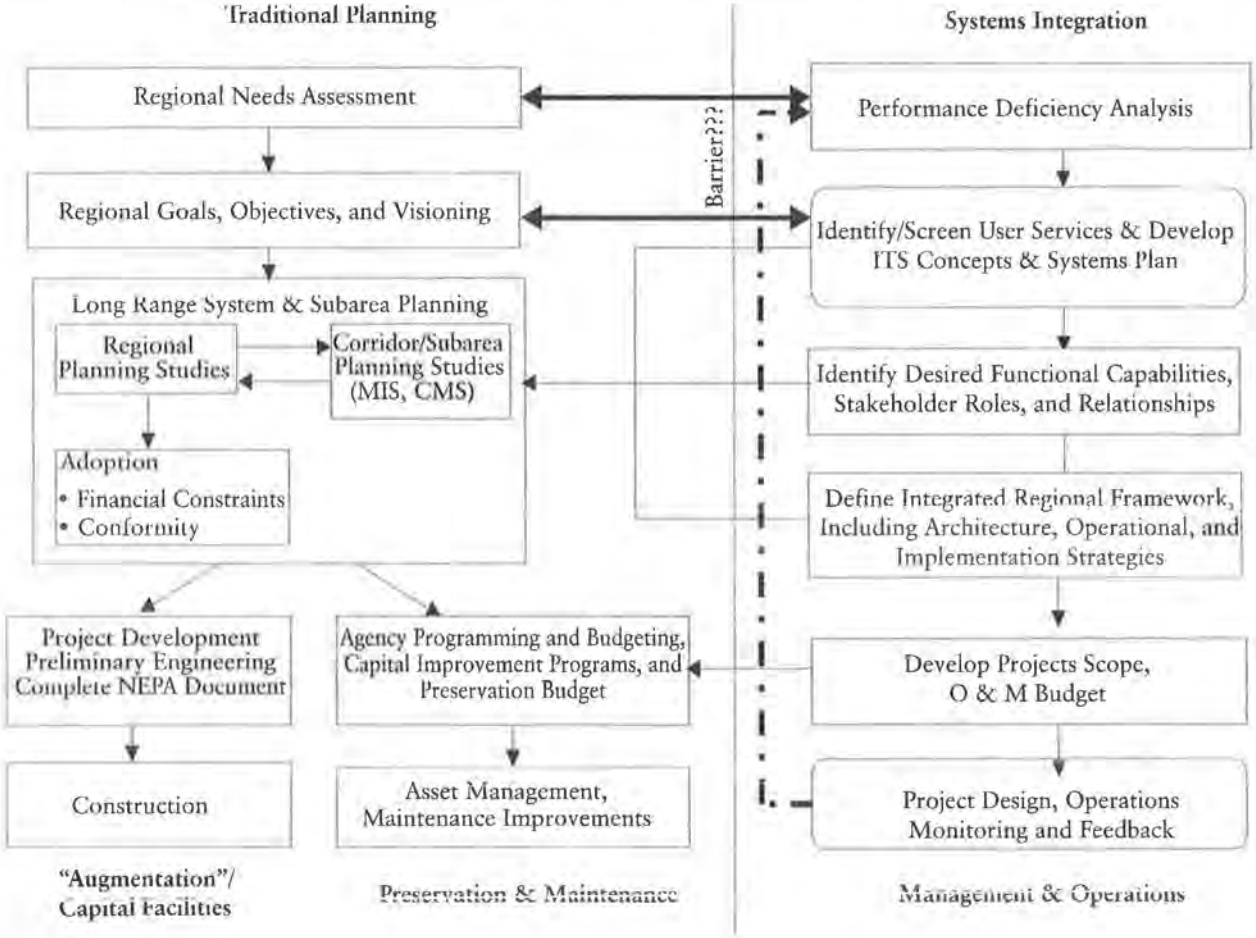

FIGURE 1 Transportation decision-making process elements.

reflecting current realities, institutional barriers, not technical barriers, keep these processes apart. This reality emphasizes the importance of the complete range of mainstreaming activities that have been discussed.

Beyond Mainstreaming to Reinvention

Although the challenges to mainstreaming may seem formidable, future progress is ensured by important context forces. The logical outcome of these forces is likely to induce change in several dimensions that will substantially affect the level and type of infrastructure-related transportation services that are delivered in the future, as well as the institutional arrangement for their delivery. Most of the forces that have been cited are external to current transportation institutions. It is important, therefore, to consider the efficient and effective response as a matter of policy. Just as the existing transportation planning and programming process and institutions were invented for a previous mission, they can be reinvented for a new one.

The reinvented 21st-century transportation service delivery model for planning and programming may include

- Acceptance of "managed congestion" as the principal performance objective of state and local planning and programming, accepting the limitations of major new capacity in most settings. This would imply a consequent priority focus on incident response, traveler information, and security-mobility attributes that reduce the impact of congestion on the individual traveler.
- Availability of archived data to the planning process to support detailed and reliable simulations of travel behavior in response to varying operational regimes and capacity additions, including the impact of information and pricing.
- Incorporation of the full development and deployment of integrated regional ITS infrastructure into planning to better support infrastructure owners in terms of their day-to-day service delivery, with secondary consideration of long-term capital improvements and preservation. The shift to a strong operations orientation may take place only after sufficient ITS deployment has occurred such that a "threshold effects" demonstration of the impacts and benefits is visible.
- Improved technical understanding of the synergism potential among reinforcing operational strategies, including the as-yet-untested impact of a ubiquitous, high-quality supply of information on demand.
- Use of information technology and distributed systems to forge a series of overlapping but coordinated virtual coalitions for specific operations purposes, without relying on a single institutionalized agency or entity and guided by a common understanding of systems architecture and protocols.
- Increased role of the private sector in outsourced development and operation of systems according to new nonintrusive technology and increased commercialization of data-collection distributions and dissemination, including private entities that provide operations services on a multijurisdictional basis in a "broker" role.