Summary Results of the Management System Integration Committee

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Colorado
Florida
FHWA
Michigan
Missouri
Oregon
MTC (Oakland, CA)
PIMA Area COG (Tucson, AZ)

Part 1. Introduction

The MSIC is a committee of state and regional transportation agencies that has been meeting quarterly since January 1996 to address issues pertinent to the utilization of integrated objective information into the transportation decision making process. This interest grew out of the advent of the ISTEA management systems and the opportunities and challenges that accompanied them. The MSIC is supported by the Federal Highway Administration (FHWA) and has been recognized by AASHTO's Standing Committee on Planning (SCOP) and the U.S. General Accounting Office for its work regarding management systems.

The MSIC's task is to address the "integration of management system outputs into the decision making process" and to address issues pertinent to integration between the systems. The MSIC firmly believes that such comprehensive integration is feasible and can be implemented at less cost than continued pursuit of uncoordinated systems.

This Final Report summarizes the committee's work, presenting it as a synopsis of the decision support tools in place in the member agencies, with a view toward the possible integration of these tools within a broader decision-making framework. The survey of tools presented here is not intended to be exhaustive, nor is it claimed to represent the state-of-the-practice. Instead, the presentation is intended to spotlight the very practical and typical issues that arise in transportation agencies when attempting to use management systems in an integrated fashion to provide objective information to decision-makers at all levels of the organization.

Key Goal:	Objective information for decision-making at all levels of the organization.

1.1 PURPOSE OF MANAGEMENT SYSTEMS

Broadly speaking, management systems are systematic procedures and tools to provide objective information to decision-makers. To accomplish this goal, management systems typically include the systematic collection and management of inventory, condition, performance, and activity data, and the use of analytical methods to process the data into information that is useful to a wide range of decisions typically made in transportation agencies. Successful management systems also feature organizational strategies to develop and maintain the cooperation of all affected stakeholders, including those who produce the original data, those whose decisions are informed by the resulting information, and those who are affected by the decisions.

Key issues:

- Agency-wide cooperation
- Relevance to all decision-makers
- Value system flexibility
- Cross-disciplinary communication
- Efficient use of data
- Incorporation of subjective values

Most transportation agencies gained their first exposure to management systems when they adopted pavement and bridge management systems. These pioneering systems exploited a relatively firm scientific understanding of engineering and economic issues within their specific disciplines to produce objective information. The evident success of these systems in supporting engineering decision-making led the Congress to mandate a much broader application of the same principles in the Intermodal Surface Transportation Efficiency Act of 1991, known as ISTEA.

ISTEA and its subsequent regulatory language broadened the conventional definition of management systems along several important dimensions. Not only did it extend the definition to new disciplines, such as safety, planning, and operations; it also implied that the rigorous quantitative data and analysis that had succeeded in traditional engineering fields could be extended to areas much less well understood. In addition, the legislation strongly implied that even the information already developed in pavement and bridge management systems would be extended to support planning-related decision-making that is not confined to specific types of infrastructure.

This broader vision of management systems focused attention on the need for decision support tools that could cross organizational boundaries among diverse groups with different levels of technical expertise, different vocabularies, and different value systems. Even the most objective information can vary in importance, depending on the value systems of the people using the information. Never before had this need been spotlighted so directly, and in this light the states recognized numerous barriers still to be overcome, including the means by which the diverse values, disciplines, and facility types could be fully integrated into the decision-making process.

The National Highway System Act of 1995 made the management system requirements optional, largely at the urging of the states. However, subsequent research by the AASHTO Standing Committee on Planning (SCOP) and the US General Accounting Office (GAO) found that the states were strongly supportive of the goals of the management systems, but objected to the deadlines and sanctions embodied in the ISTEA legislation. A SCOP survey found that all of the responding states planned to continue implementation of the pavement, bridge, safety, and congestion management systems, even without a Federal mandate. Significant percentages (81% and 72%, respectively) also planned to continue work on the public transit and intermodal management systems. Although removal of the mandate has in many cases adversely affected the level of resources and priority given to management system implementation in transportation agencies, it has had the positive effect of allowing these agencies a more reasonable amount of time to come to grips with the substantial effort of defining what tools are needed and how they should be integrated.

In opposing the ISTEA mandates, an argument frequently given by the states was that the data requirements of the systems were viewed to be excessive. It is surprising, then, that the subsequent SCOP survey found a substantial majority of the respondents with the opinion that the management systems they are implementing do not have excessive data requirements. The MSIC believes that the difference between these seemingly contradictory statements is that transportation agencies are already collecting enough data, but have not yet learned how to use the data collection effort to its highest potential to inform decision-makers. There is a strong feeling that the best allocation of resources among data collection activities is not yet well-understood enough to legislate, and probably varies from one organization to another in any event.

As the scope of management systems expands beyond traditional engineering disciplines, it increasingly encounters important issues for which quantitative data are lacking. This situation exists in all agencies, large and small. In many cases, especially with value judgments, it is unlikely that satisfactory quantitative methods could ever be developed. Each in its own way, MSIC member agencies have addressed this issue by attempting to develop tools which provide clear, evaluated, viable choices, making it as easy as possible for decision-makers to make the necessary value judgments in a well-informed, consistent way.

1.2 DEFINITION OF INTEGRATION

Integrate: *to form, coordinate, or blend into a functioning or unified whole; unite.*

It has been widely recognized that the ISTEA taxonomy of six "management systems" and one "monitoring system" is an accidental, incomplete, and distracting way of classifying the issues to be addressed in management systems. For example, pavements, bridges, intermodal facilities, and transit facilities and equipment are not the only important types of infrastructure that an agency might want to manage, and are not mutually-exclusive groups. Safety is only one of many important sets of values, and congestion is only one of many important problems to be managed. When too much focus is placed on the technologies of specific kinds of facilities, the danger is irrelevance to non-technological decisions or decisions that are not confined to one type of infrastructure. When focus is placed on only a small number of selected values or problems, the system is unbalanced and loses its usefulness to the large number of decisions that affect multiple values and problems.

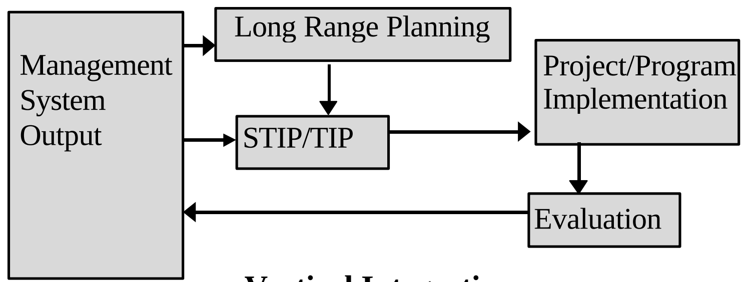
A large part of the difficulty the states experienced in implementing the ISTEA mandate stemmed from the confusion of definitions in the legislation. The MSIC believes that the full potential of management systems can best be achieved by setting aside the ISTEA definitions and mandates, and instead organizing the scope of management systems around the objectives to be achieved by these systems. If the point of these systems is to provide objective information to decision-makers, then it is important to identify the kinds of decisions that might benefit, the information requirements of these decisions, and the tools which might feasibly provide the required information. Even with pavement and bridge management systems, which have proven their value to engineering decisions, it is important to take a broader view of how these systems might contribute to broader statewide policy and programming decisions in an integrated fashion.

Integration Defined:

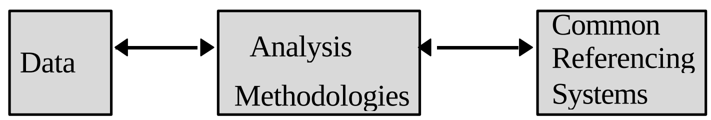
- The coordination of inputs, processes, and outputs of the systems
- Linkage between systems such that:
  - the dynamics of one system will affect other systems as appropriate
  - data is consistent and easily accessed, displayed, and transferred between systems
- The systems' information is used effectively and consistently in decision making processes, specifically including planning

A broader systems view of the scope of management systems can facilitate agency-wide relevance and cooperation, ensure that all legitimate value systems are addressed, identify and then address inter-disciplinary communication needs, identify opportunities for data collection efficiencies, and promote the consistent and well-informed application of necessary professional judgment.

Relative to the ISTEA definitions now being followed by most of the states, there is a need for both vertical integration of management systems into the real decision-making process of each organization, and horizontal integration of the systems with each other so they can contribute effectively to larger agency decisions. Both of these types of integration can be addressed with the approach described here. The case studies presented in this report and the supporting documents show some good examples of the current thinking of a few states on how this can be accomplished.



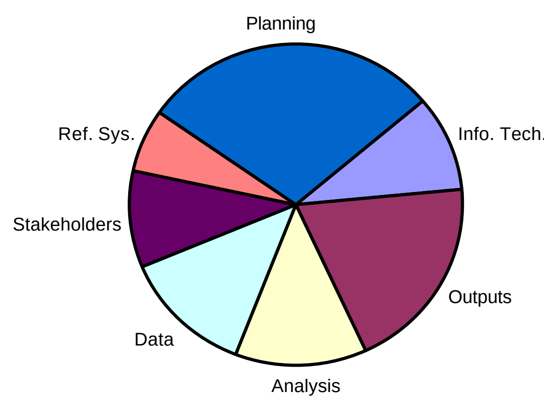
Vertical Integration



Horizontal Integration

Integration strategies typically need to address many inter-related issues, as depicted in the "integration pie." Examples of management system integration are:

- compatible outputs that allow cross-program comparison
- compatible analysis methodologies
- consistency of data used by multiple systems
- impact of one system's changes on the other systems
- data interfaces are linked (including GIS, common referencing system)
- common timelines and consistency of reports and outputs
- effective utilization of outputs in local and statewide planning and other decision making processes
- performance measures that allow agencies to measure system performance across functional classes, modes, and jurisdictions



The "Integration Pie"

1.3 BACKGROUND ON THE MSIC

The Management Systems Integration Committee (MSIC) is a group of representatives of state, local, and Federal agencies formed to provide a means of sharing knowledge and providing guidance to all agencies interested in the integration of management systems. After seeing the products of the MSIC's first exploratory meeting in January 1995 in Denver, Colorado, the FHWA provided funding to continue the work of the committee. In a series of meetings during 1996 and 1997, the committee developed a preliminary framework for addressing integration issues, and prepared numerous case studies of member agencies' attempts to address these issues. The case studies are not meant to be exemplary, but are intended to spotlight typical approaches to these issues and to identify potential topics for future research and development that might be of value for all states. The products of this work are documented in a series of Proceedings, and in this Final Report.

At its first meeting the committee identified "integration of management system outputs into the decision making process" as its highest priority. Because funds invested in management systems only buy information, it is essential that the information is useful to improve decision making. This customer focus should drive management system development and implementation. Additionally, the successful resolution of integration issues among the systems themselves, which the MSIC worked on in parallel with this highest priority, will result in higher quality information at less cost. The MSIC firmly believes that comprehensive integration is feasible and can be implemented at less cost than continued pursuit of uncoordinated systems.

Purpose of the MSIC:

- Share knowledge and experiences of key states/MPOs, and identify issues and challenges regarding the integration of the Management/Monitoring Systems.
- Deliberate and resolve integration issues, and identify best practices, for recommendation to other states/MPOs.
- Foster cooperative and joint development relating to the integration of Management and Monitoring Systems.
- Identify the areas of need for integration work at the national level.

With this Final Report, the MSIC's work is now complete. Recommendations for future research and joint development have been made separately to various bodies, and will be pursued by other groups established for those specific purposes.

1.4 CONTENTS OF PROCEEDINGS

The MSIC has produced five volumes of Proceedings, each describing the results of one or more committee meetings. Two of the meetings did not produce Proceedings, and the final meeting results are incorporated into this final report. All of the volumes follow a similar format:

- Identification of participants, including invited guests;
- Background on the purpose of the committee and the definition of integration;
- A summary of the issues addressed in the meeting;
- Case studies from the participants;
- Other issues discussed by the group or presented by guests.

Contents of Proceedings:

- **January, 1995 (Denver)**
  - Background on each agency's management system efforts
  - Federal perspective on future management system work
  - Data collection efficiencies
  - Interface with the planning process
  - Objectivity of the systems
  - Common performance measures
  - Joint development efforts
  - Integration of CMS/PTMS/IMS
  - Future of the committee
- **January, 1996 (Washington) and May, 1996 (Oakland)**
  - Why do management systems without a mandate?
  - Current status of each state's efforts after lifting of the mandate
  - Decision-maker interviews
  - Integration with the decision-making process
  - Common referencing systems
- **August, 1996 (Boca Raton)**
  - Integration with the decision-making process
  - Integration into long-range planning
- **October, 1996 (St. Louis)**
  - Integration with the decision-making process
  - Integration into the STIP/TIP development process
  - Performance measures
  - Performance measure references
- **May, 1997 (Portland, Oregon)**
  - Evaluation of implemented actions
  - Management system clearinghouse
- **July, 1997 (Deerfield Beach, Florida)**
  - Future direction
  - Program implementation, maintenance, and operations

1.5 FUTURE DIRECTIONS

The MSIC believes strongly in the value of joint development projects to meet agency needs in innovative and cost-effective ways. In particular, the recent success of FHWA and AASHTO in developing the Pontis bridge management system has been discussed as a model for possible future activities. The committee feels that the framework documented in this Final Report provides a good foundation for an innovative set of tools that might be produced by a joint development process. Any development effort would first have to produce a more focused definition of the tools to be developed, and the standards and conventions which would have to be adopted in order to make the tools usable by a large number of agencies. The Pontis system, for example, needed widespread adoption of standard data definitions and a standard bridge inspection procedure before the software could be implemented as a joint development product. A coordinated strategy involving many different state and Federal agencies was required in order to make this happen.

Federal participants in the MSIC expressed a strong interest to continue to assist in any follow-on projects that might be produced along these lines. The General Accounting Office, in its 1997 report on the status of management systems (GAO/RCED-97-32), recommended that the Federal government continue to work with the states to define the types of technical support required, and to provide such support whenever possible.

The MSIC believes a systems approach holds promise as a means to foster an integrated transportation planning and decision making process. A systems view of the transportation system inherently moves managers from focusing on managing components to managing the components together as a system. The resulting data collection, performance measurement and decision making processes will look different when an institution is managing a system rather than a component of the system. In particular, substantial data collection efficiencies may be achieved when there is a systems view of how the data will be used. It is the MSIC position that future work in this area should advocate the systems view presented in this report, should foster research efforts which build on these concepts, should develop case studies of attempts to implement them, and should identify barriers to further implementation.

Part 2. Integration with the Decision-Making Process

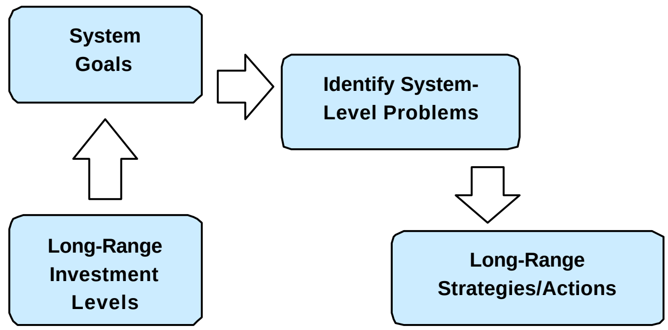
Management systems are most valuable when they are modeled around the desired human processes by which decisions are to be made. This perspective is quite different from the concept of a "black box" which issues optimized decisions, and is also quite different from a mere record-keeping system which records and plays back the outputs of an existing and potentially flawed decision process. Management systems can be powerful catalysts for organizational change. A successful strategy for management system design starts with documenting the desired decision-making process, including clear responsibilities for all participants, balanced attention to the concerns of all stakeholders, and a full-system perspective on policy/program alternatives and outcomes. When decision-maker buy-in has been achieved on the process, it becomes easier to specify information requirements and tools that produce the desired information to inform each participant.

With this perspective, the MSIC decided to develop a high-level model of the decision-making process to be served by the management systems, and to present its findings organized according to this model. The committee believes that this general model reflects the direction toward which many transportation agencies have been trying to evolve over the past 20 years, with varying degrees of success. It is hoped that this model will be stable enough in the future to provide a durable organizing framework for thinking about integrated management system requirements.

General model of the decision-making process:

- **Long-range planning**
  Set system goals
  Determine long-range investment levels
  Identify system-level problems
  Prioritize long-range strategies and actions
- **STIP/TIP development**
  Determine investment levels: project or program level
  Identify and refine specific problems and solutions
  Prioritize STIP/TIP strategies and actions
- **Program implementation, maintenance, and operations**
  Accomplish detailed design
  Construct project or implement program
  Maintain infrastructure or operate program
- **Evaluation of implemented actions**
  Monitor project/program to compare performance with intended results
  Reassess applicability of strategies and actions given findings

2.1 LONG-RANGE PLANNING



For the purposes of management system support, the long-range planning process can be divided into four related parts, each having its own information requirements. It is evident even from this initial look at statewide planning that this model will produce a set of information and decision support tool requirements quite different from those proposed in the ISTEA.

Set System Goals. Decision-makers set system goals, often called policies, for various components of the transportation system. Many agencies set quantified goals for the capital assets of their transportation system in order to maintain their infrastructure at some desired level. More and more agencies are beginning to quantify goals for the system-wide *performance* of their transportation system, such as the safety or mobility provided by the system.

Determine Long Range Investment Levels. Investment levels are then set which will achieve the system goals within a prescribed time frame. Funding is typically allocated to certain categories of projects, such as resurfacing, safety, public transportation, capacity, etc. Ideally, these decisions should be from a total "system" approach, looking at the systemwide implications of changes to any one part of the transportation system.

Identify System Level Problems. The third step is usually to look at where the problem areas are—accelerating deterioration, growing congestion, increased accidents, etc. This step pares down the areas of focus for evaluating long term actions.

Prioritize Long Range Strategies and Actions. Finally, long term strategies and actions are determined to focus on the problem areas. Carrying out these strategies and actions should result in achievement of the system goals if the appropriate funding (investment level) has been provided.

The decision-makers in long-range planning are elected officials, senior management, and the staff who provide information to them. Although some of the required information is public input and subjective judgment, there is an important ingredient of quantitative input which most decision-makers will use — indeed, cannot ignore — if it is provided at the right level of detail and has credible processes of data collection and analysis behind it.

Inventory

Tools for long-range planning:

Inventory
Performance measures
Monitoring
State of the System report
Identification of needs
Predictive capabilities
"What-if" analysis

The system inventory consists of raw information about the primary components of the transportation system. Examples are bus/transit fleets, pavement and bridge types including structural characteristics, traffic capacities of roadways and other facilities, facility locations and major characteristics, and network characteristics (i.e., roadway and bridge geometrics, railroad track quality, HOV locations, bicycle lane locations). The concept of an inventory can also be extended to include non-assets such as private-sector transportation services, land-use patterns, facilities owned by other jurisdictions, climate data affecting system performance, vendor data, and customer data. Geographical queries and flexible summarization are important capabilities for long-range planning.

Nearly every state has a computerized inventory of bridges and pavements supporting management systems. Bridge inventories are highly standardized because of the FHWA's National Bridge Inventory and widespread adoption of Pontis. This has facilitated an active long-term effort to build decision support tools usable by large numbers of states. No such standardization exists for pavements.

Oregon's Congestion Management System features strip charts showing the highway segments where congestion occurs now and will occur in 2015 and where it is most cost-effective to make improvements to reduce travel times. It notes the segments where vertical grade and roadway width are inadequate and where highway management affects travel time.

Performance measures

Performance measures are operational characteristics, physical conditions, or other appropriate parameters used as benchmarks to evaluate the adequacy of transportation facilities and needed improvements. Within categories, like mobility, performance measures are established to enable a like comparison across modes (e.g. all modes calibrated to person miles of travel). Integrated performance measures enable compatible comparison of strategies and actions across a variety of decision types.

The Pima Association of Governments has established several candidate performance measures for the assessment of alternative long-range transportation plans under development in the Tucson metropolitan area. These include vehicle emissions, travel time by auto (average travel speeds), lane-miles of roadway system congested, vehicle -miles traveled under congestion, mode share, transit ridership by route, bicycle trips, and walk trips.

Colorado DOT has established performance measures for its pavement network, which include needed preservation cost, excess user cost, excess injuries and fatalities, and ride quality.

Monitoring

Systematic and routine gathering of performance data on the primary components of the transportation system is necessary to detect trends that may trigger the need for action. Examples are traffic volumes, physical condition ratings, air quality measurements, and crash statistics.

Oregon DOT's Pavements Unit monitors progress in reaching its performance goal by surveying for distress, skid and ride quality annually. The unit collects distress types, severities and quantities for NHS roads using an objective index, and uses a subjective rating system for non-NHS roads.

In the early 1990s, a committee of states working on the Pontis bridge management system recognized that condition data collected by every state at the time did not provide enough information to estimate the severity or extent of damage. This recognition led to the development of a Commonly Recognized (CoRe) standard for condition rating. This new inspection procedure is now used in nearly all the states.

State of the System report

A fundamental report from all management systems, whether performance based or asset based, is the "state of the system." The "state of the system" report provides a comprehensive snapshot of the transportation system in terms of its condition and performance. Examples are regional or statewide safety problem locations, facility condition histograms and trend lines, air quality maps, and congestion trend maps. Such reports are used to support funding requests, to set corridor priorities, to demonstrate effectiveness in addressing transportation system needs, and to establish benchmarks for determination of needs.

Colorado DOT used a systemwide summary of its old "windshield" survey data in 1993 to show that only 38% of state highways were in good or fair condition, compared to the established goal of 75%. This simple observation led to a major increase in pavement investment.

Crash data, supplemented by other planning data, are used by Florida DOT to produce statistical analyses that identify probable hazardous crash locations. District personnel, in turn, use this information to develop the safety and rail-highway crossing improvement projects.

Identification of needs

Needs are indicated in locations where performance has fallen below standards, or where life cycle models have shown that strategic preventive actions may be cost-effective. The identification of all types of needs may be supported by monitoring system performance and comparing performance measures against established benchmarks or trigger levels. Benchmarks and triggers should be subject to periodic review so that they reflect the overall state of the system, and the current policy and funding environment.

The congestion management system plays a very strong role in identifying problems at the MTC, by spotlighting failures to meet pre-established performance standards. As valuable as this is, there is a concern that focusing too narrowly on congestion may lead decision-makers to mis-diagnose transportation system needs or to underestimate their scope.

Florida DOT identifies bridge replacement and repair needs by comparing performance data with standards for structural condition and functional characteristics.

Predictive capabilities

There is an important time dimension to long-range planning due to the lead time of projects, the possibility of preventive actions, and the need to match future programs to expected funding. Since the transportation system is constantly changing, predictive capability is extremely valuable in the establishment of future benchmarks and funding requirements. Also, predicting the physical deterioration of assets or changes in mobility performance due to prospective actions under consideration (including do-nothing), is essential to a balanced and strategic evaluation of policy alternatives. Life cycle analysis can be a derivative of such modeling. This can include replacement schedules for bus fleets, remaining service life analysis of pavement, and the impact to capacity along a certain corridor given projected traffic volumes.

> Asset management systems typically use deterioration models to predict changes in physical condition over time. In Pontis, for example, historical data on bridge inspections and maintenance activity are used to estimate the probability that each type of structural component will make the transition from one condition rating to another in any one-year period. Aggregated over an entire bridge inventory, this tool can forecast the number of bridges that are likely to reach a condition requiring repair within any given planning horizon.

> Oregon DOT uses a modified version of HPMS with traffic growth models to forecast travel times on highway segments. This is very helpful in determining the relative timing of competing investments.

"What-if" analysis

The power of the above tools is maximized when the full complement is available and can work together efficiently. It is extremely valuable to decision-makers if they can propose a specific policy or funding level, and receive speedy feedback in terms of changes to system performance, funding requirements, and opportunity costs. A strong argument for automation of all the above tools is the desired capability to evaluate a large number of alternatives very quickly, thus maximizing the completeness of information provided to decision-makers.

> Oregon DOT uses its predictive capability to forecast the long-term performance changes that may result from alternative solutions to congestion problems, ranging from modest traffic management strategies to major capacity and geometric improvements. This lays the groundwork for debating and prioritizing strategies and actions for alleviating the identified problems during the corridor planning process.

> As asset management models have become more efficient and data have become more widely available, they are increasingly used to systematically identify and evaluate continuous ranges of solutions. FHWA, for example, has developed a model based on Pontis to forecast the future state of the nation's bridge inventory as a result of alternative levels of Federal investment.

Findings

1. A basic piece of information from all Management Systems (MS), whether performance based or asset based, is the "state of the system." MSs should answer the following questions:

- How well is system performing?
- How well are the transportation assets being maintained?

- What is the physical condition of the system?

These "state of the system" reports should be available in multiple levels of aggregation, depending on the level of the decision-making. There should ultimately be the capability to boil down the system to percents of "good, fair, and poor" or "acceptable/unacceptable." With the national trend toward increased flexibility in transportation funding, decision-makers require "state of the system" reports that cover the major components of the transportation system so that they can make informed decisions.

2. In order to answer these questions, an underlying implication is that MSs are inherently based on standards or objectives. Questions such as "how well is the system performing" can only be answered if there are accepted standards/objectives for physical condition or performance. Standards may range from clearly articulated quantitative measures to simply deviations from past trends. These standards should be clearly articulated and understood by users of the management systems' information. Agreement on standards and objectives can be difficult when there will be funding allocation implications. Management and major stakeholders must understand the standards/objectives and agree to them. For example, often decision makers and users misinterpret information from an asset-based management system as applying only to the maintenance needs and conditions. However, often such systems measure condition relative to current design or functional standards (such as the width or load capacity of the bridge).

3. MSs should include the ability to assess the financial implications of altering assumptions and standards. What if the schedule for replacing assets is extended--what will be the financial implications? If pavement is maintained at 90% fair or better, what will be the cost over a certain number of years? For example, in the San Francisco/Oakland region the PTMS has used a standard bus replacement schedule of 12 years across all systems. With anticipated drops in federal funding, MTC will be looking at the financial implications of alternative bus replacement schedules. To do this, the PTMS is being modified to include an analytical module that provides data on the transit operating cost implications (i.e., changes in maintenance costs) in the event bus replacement schedules are changed.

4. What-if analyses are more useful in long-range planning if they can optimize the results. Optimization reflects a value structure. A system optimized to preserve the transportation system, for example, will yield different results than one optimized to stimulate economic development. Optimization can be based on

- performance or level of service (What is the optimal level of service?) or
- budget constraints (How should funds be allocated among competing needs in the same inventory or among different inventories?)

The results can be optimized

- by using a benefit/cost analysis (How can we get the most benefit for a given investment?) or

- by using non-dollar measures of effectiveness (What actions, at what cost, should be taken to achieve a performance goal?)

For example, we can achieve 90% fair or better pavement conditions on statewide roads and 66% fair or better on district roads for $80 million a year. Alternately, in order to achieve 90% fair or better pavement conditions on all state jurisdiction roads we need to invest $100 million a year.

5. While asset based MSs typically directly calculate the financial implications of action (or lack of action), performance based MSs do not necessarily provide such a calculation. Performance MSs may only act as a means to signal the responsible agency to take a closer look at the performance of the system or sub-area. The financial implications, as well as the non-financial implications, may only be understood after further examination of the performance problem and the examination of alternative mobility or safety strategies.

6. To help ensure integration among systems, the following should be done:

- Clearly articulate the underlying assumptions/objectives/standards used in the different systems and document them.
- Ensure that standards that are common to diverse inventories are the same.
- Ensure that data and analysis methodology that are common to different systems have common data definitions and are consistent.
- Where MSs are used to calculate a single numeric score or rating, test and evaluate the various components that go into that score for consistency among systems.

7. Generally there is consensus throughout the transportation industry on the design standards underlying asset based systems. There is less consensus for performance based MSs such as CMS. "Good performance" or mobility objectives are more reflective of the particular concerns of individual regions and states. Such concerns, for example, often vary between rural and urban regions. Some regions may focus on reducing congestion, while others may focus on accessibility, cost effectiveness, etc. However, as with asset based MSs, clearly articulated performance objectives/standards are critical no matter what the performance objective and should be set by policymakers. Standards and objectives are a way of articulating to the customers (public) what the policies of the agency are, and a way of delegating authority to agency staff.

8. At a system level, performance based measures, whether called management systems or not, have proved useful to measure how performance of the system varies depending upon alternative investment strategies. This would be a desirable use and practice for MPOs and States. For example, regional plans of larger MPOs will often develop alternative regional investment strategies and measure how the performance of these strategies varies. State of the system reports help the MPO select a preferred investment strategy for implementation in the regional plan. This process may only be

appropriate for state agencies and larger MPOs. A similar process is typically used at a corridor level to measure the performance of alternative investment strategies.

9. The introduction of objective performance-based information into transportation decisionmaking helps delineate the discrete components of decisions to be made so that each component can be debated and decided upon individually, then weighted against other components for a comprehensive decision. Transportation decisionmaking in the public arena is very complex, with numerous conflicting and competing needs. Those needs (decisionmaking components) that lend themselves to objective analysis, which can be quantified with a reasonable degree of confidence and credibility, are directly supported by the provision of MS information. Along with these objective components of decisionmaking are many and varied subjective components, such as social equity, political pressures, public sentiment, windows of opportunity, etc. These subjective components are completely valid and should be fully considered. One of the main benefits of MSs information is that it helps force subjective components into open debate, since the objective components speak for themselves. This helps keep the debate clear, thus limiting the potential for exaggerated claims of infrastructure condition, safety, or mobility.

10. In order for objective information to be fully considered in the transportation decisionmaking process, long range system goals should be quantified. Without quantification, measuring the attainment of goals is difficult or impossible, and quantified information has much less potential for improving decisionmaking. Principles espoused by experts on total quality management emphasize use of numeric goals and a data-based systems approach rather than a project-by-project approach. Finally, the quantification of goals allows the staff of the agency to carry out the achievement of the goals in the most efficient way with relatively little interference while still being completely consistent with the desired outcomes of decisionmakers.

11. Transportation decisions are being made every day without adequate information about the transportation system. Without good information, goals can be unrealistic or less meaningful. Setting goals should be an iterative approach where decisionmakers can evaluate the consequences of proposed goals on the total system given available revenues. MSs can play a key role in projecting scenarios and monitoring the effects of long range decisions.

12. Traditional analysis methods for transportation assets are based primarily on physical condition (e.g. depth of pavement rutting, % of cracked concrete girders.) This is very useful for engineers for use in project scoping and design. Higher level decision makers are typically concerned with broad funding decisions that require a different type of information. A “needs” based analysis is much more useful to them because it addresses the financial implications of various scenarios of overall asset physical condition. A needs based analysis considers deterioration rates in determining the financial “needs” of a given piece of the inventory. State-of-the-art computerized asset management systems put this ability at the fingertips of management systems professionals. The Colorado DOT has done a great deal of work in this area and will gladly discuss this work with interested parties.

13. The process of long range planning requires significant cooperation between numerous and varied stakeholders. Many partnerships have been initiated by the management systems process. For example, in the development of safety management systems, diverse professionals representing traffic engineering, driver behavior, enforcement, and emergency services often sat down together for the first time to try to begin to coordinate ways to save human lives, reduce injuries, and minimize property damage.

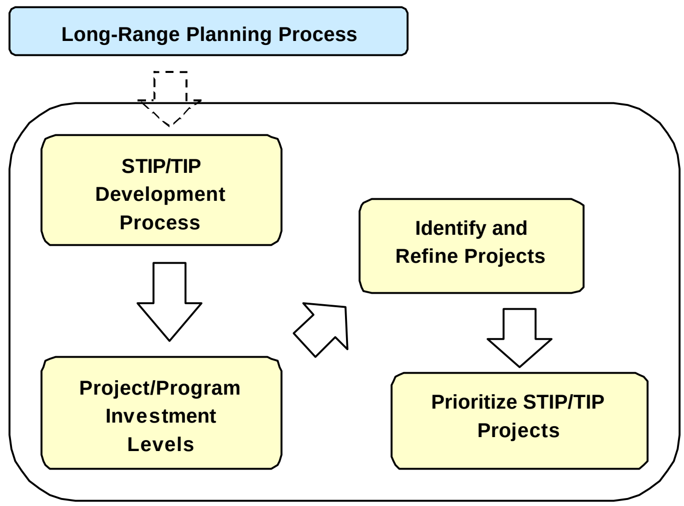
14. As experience using the systems increases, the boundaries between the systems begin to evaporate. The SMS, CMS and PMS, for example, might locate problems/needs in the same highway segment. Planning and project selection processes can then focus on the problem area. Those involved in developing strategies to solve the problem, possibly a cross-functional team, need compatible data for the segment from each of these management systems. The data could appear on a GIS application that integrates the information and changes the focus from the individual systems to the performance of the transportation system as a whole.

15. One stop shopping can greatly facilitate sharing of data throughout a transportation agency. It saves time and effort for those seeking information, greatly increasing the likelihood that the information will be used. Putting transportation information into silos should be avoided as much as possible by combining ISTEA management systems information with all other relevant information needed for decisionmaking. One stop shopping does not necessarily mean that all transportation information is stored in an enterprise data base or accessible via a GIS. The key is to make data conveniently accessible, which can be done with contact persons, distributed processing, intranets, etc.

16. Mock up reports should be developed as part of establishing user requirements for the management systems. They are one of the most effective ways for users to describe what information is needed from a management system and how it should be presented. Mock up reports have been very successfully used in software development. They are also very successful for hardcopy reports to be given to decisionmakers. Producing comprehensive mock up reports also emphasizes the benefits of uniformity and compatibility between systems.

17. Although many state DOTs recognize the important role of technology in developing management systems, they have not fully used/optimized the benefits of such systems. Deterioration and prediction models, Computer Aided Design/Drafting (CADD), Geographic Information Systems (GIS), and other systems are well underway as separate efforts in many states. States are beginning to recognize that some of the needed data are nonexistent, duplicative, difficult to retrieve, or incompatible. As statewide transportation planning becomes more complex and processes change accordingly, it becomes imperative to migrate to a better integrated and planned transportation system.

2.2 STIP/TIP DEVELOPMENT



STIP/TIPs (state and metropolitan transportation improvement programs, respectively) are practical sets of projects and programs designed to achieve the goals and objectives established in long-range plans. STIPs and TIPs can generally be distinguished from long-range plans by their greater degree of project or program specificity, readiness, and prioritization, and funding constraints. Additionally, STIPs/TIPs are a shorter-range programming of projects (minimum three years) and thus represent the intermediate step between the long-range plan and ultimate project delivery.

Investment levels. The list of projects and programs in the STIP/TIP must match the jurisdiction's funding capability. This constraint forces the STIP/TIP process to evaluate program tradeoffs and to develop accurate cost estimates. Since funding is a variable, the process benefits from objective information on the cost of alternative performance levels, the consequences of sub-optimal investment levels, and the effects of alternative allocations among program areas.

Project definition. Projects and programs eligible for inclusion in a STIP/TIP need to have been identified in the metropolitan long-range plan or linked to the goals and objectives established in a state's long-range plan if that plan is not project specific. Management system tools can be useful in preparing candidate projects from identified needs, including scoping and cost estimation.

Selection and prioritization. Project selection can encompass many factors, including: a) the degree to which a project meets threshold requirements; b) project readiness; and c) its ranking among like-projects or among unrelated projects which are eligible for the same funding sources. The management systems can assist in project selection and can provide objective information for use in priority-setting.

Inventory, performance measures, and monitoring

Like the long-range planning process, management systems rely on an inventory of the facilities, equipment, and other items being managed, a systematic means of measuring performance in terms of economics and service to the public, and periodic data collection to determine the current state of each component of the system. In a management system which supports both planning and programming, it is typical for the same resources to be used for both purposes. However, while long-range planning can produce satisfactory results with sampled data collected infrequently, the STIP/TIP process requires more comprehensive coverage.

Tools for the STIP/TIP:

Inventory, performance measures, and monitoring
Identification of needs
Predictive capabilities
Project selection methods
Prioritization criteria
"What-if" analysis

Oregon DOT uses a modified version of HPMS to forecast travel times on highway segments. Unlike most HPMS users, however, Oregon uses a 100% sample of state highway segments, so that the system can be used for STIP/TIP support as well as for long-range planning.

Identification of needs

Needs identification for STIP/TIP development differs from that used in long-range planning in that it operates on a shorter time frame and is more project-specific. The two processes are highly related, however, because the values and level of service standards developed in the long-range plan guide and constrain the needs considered for the STIP/TIP. While long-range plans can envision an undefined level of satisfaction of all user goals and values, the STIP/TIP must provide a firmer separation between conditions requiring action soon, and those which will be tolerated a few years longer. This process works best when it even-handedly considers all transportation values, but here the ISTEA management system scheme is particularly weakened by encouraging multiple dissimilar systems.

The East-West Gateway Coordinating Council (St. Louis) established seven priority areas as an inclusive and strategic framework to ensure that the needs of the transportation system customer constitute the principal reference points for regional project identification, selection, and priority-setting:

- Preservation of the existing infrastructure
- Safety and security in travel
- Congestion management
- Access to opportunity
- Efficient movement of goods
- Sustainable development
- Resource conservation

One of Oregon's regional offices used its pavement condition map as a base and added bridge, guardrail and other safety projects. This provided a common basis for identifying needs in a uniform way.

Predictive capabilities

Well-developed management systems are especially strong when they can provide credible predictions of the effect of candidate projects on system performance. Important parameters to be predicted include facility deterioration, traffic growth, trip generation, accident risk, project costs, long-term maintenance and operational costs, and user costs. Performance measures can be derived from these.

For accuracy, these prediction models often depend on physical behavior and other engineering factors, so prediction methods tend to be specific to certain types of facilities, such as bridges and pavements. It is counter-productive, however, to infer from this that facility-specific management systems should be isolated from each other. The section on STIP/TIP Findings, below, discusses this important issue in more detail.

> Pontis uses a variety of predictive models, including bridge element deterioration, cost estimation, and traffic growth. The deterioration model is very specific to bridges, as is the estimation of direct costs. However, traffic growth and certain indirect costs (e.g. traffic control and land acquisition) are more generic: Pontis does not attempt to estimate them directly, but instead relies on outside sources.

Project selection methods

Management systems typically provide the capability to generate and evaluate multiple feasible alternatives to address each identified need. Often, one alternative is the full implementation of all cost-effective actions on a facility or corridor. This may be accompanied by downscoped alternatives involving lower cost and lower predicted benefits. Do-nothing normally is also an alternative, whose outcome must also be predicted. In some cases, the alternative projects are quickly reduced to a single selected candidate project by use of selection criteria or optimization; in other cases, the priority-setting process selects among multiple alternatives, which may be reduced by means of a screening process. Where feasible, the latter approach is often preferred because it allows the selection of projects to be sensitive to overall funding constraints.

> The Pima Association of Governments (Tucson) uses a set of screening criteria to determine which candidate projects will be brought forward:
>
> - Funding eligibility
> - Consistency with the Metropolitan Transportation Plan
> - Support of existing land-use plans
> - Completeness and reliability of cost estimate
> - Project readiness
> - Conformance to the Mobility Management Plan
> - Adverse air quality impacts

> Pontis uses a life-cycle cost optimization model to select maintenance, repair, and rehabilitation actions generically in response to each possible condition level of each bridge element. For prioritization, then, only one set of actions is normally considered on each bridge. This is also true for functional improvements and replacement, where a set of level-of-service and design standards determines the recommendation which will be brought forward into prioritization.

Prioritization criteria

Because of the existence of funding limitations, the STIP/TIP process forces decision-makers to set priorities. In the past, this process was normally subjective and often arbitrary. In recent years, however, greater public involvement and a demand for accountability have made it necessary to adopt a more objective process, often featuring quantitative prioritization criteria. Benefit/cost analysis is frequently a valuable tool in this process, especially when it is necessary to translate facility-specific engineering performance measures into economic measures that are compatible with other systems. In general, however, any criteria that express predicted changes in system performance measures in relation to project cost, can be valuable for prioritization.

The East-West Gateway Coordinating Council ranks projects according to a cost-effectiveness index, based on project cost and a numerical score derived from the values listed above.

Oregon DOT regions use the Safety Priority Index System (SPIS) and the Accident Priority List Report to identify potential hazardous locations, prioritize safety problems, and allocate money for the STIP. The SPIS calculates an accident rating based on (1) the number of accidents at a location; (2) a rating of the accident rate (based on accidents/million vehicle miles and a probability curve); and (3) an evaluation of the severity of the accident (based on fatalities, injuries and property damage).

The Pima Association of Governments also uses a numerical scoring system for prioritization, with scores and weights assigned to the following categories:

- Air quality impacts
- Preservation of existing facilities
- Promotion of compact urban form
- Safety
- Promotion of alternative modes
- Congestion relief
- Improvement of drainage or support of other infrastructure
- Improvement of accessibility
- Enhancement of economic development
- Improvement of system connectivity
- Corridor preservation
- Other social, cultural, energy, or environmental impacts
- ISTEA Transportation enhancement activities
- Project readiness

"What-if" analysis

Since funding constraints are so important to the STIP/TIP process, decision-makers need tools for evaluating the effect of funding uncertainty and fund-raising strategies on the program. For the same reason, it is also important to have tools that inform decision-makers of the opportunity costs of each potential use of marginal funding. When funding is limited, directing money to one worthy project means that another project is deferred. Since the ability to quickly generate and evaluate multiple project and program alternatives in "what-if" fashion is so valuable, this is often the factor that leads decision-makers to want automated support.

Pontis uses life-cycle cost savings, travel time (delay), and accident risk as direct performance measures, but then converts the latter two to user costs so it can use a benefit/cost ratio for prioritization. The system's priority-setting features recognize annual budget constraints, and include an incremental benefit/cost algorithm to arrange the candidate projects so that the maximum user and agency cost savings is achieved each year. Because the process is automated, a user can change the budget constraints, level-of-service standards, or specific attributes of any individual projects, and readily see how the project selections, priorities and schedule are affected.

Even though certain inputs to this process (e.g. deterioration models) are specific to bridges, the prioritization and what-if features are highly generic, usable for any type of project. More importantly, Pontis would be equally effective if instead of using its internal programming tool, its candidate projects (with their cost estimates and performance measures) could be fed to an outside programming tool developed for the full scope of the STIP/TIP process.

Findings

1. Development of TIPs and STIPs necessarily requires the sharing and exchange of information within individual agencies, as well as between agencies of different jurisdictions and responsibilities. Further, agreement on the meaning and relative importance of analyses performed on data combined from many sources is necessary if STIP and TIP documents are to obtain the necessary agreement among the affected parties. There are two aspects to data and analysis sharing. These are:

- Technical Considerations -- These include such things as data formats, storage, and analysis methods. If agencies are to share information there must be some agreement on at least the technical details of how data is to be stored, formatted, and transmitted between the agencies.
- Definitional Considerations – These include agreement on what the underlying data means, as well of the resulting analyses.

Frequently the same terms are used to describe the data to be shared. Since the data are developed for different reasons by different agencies however, the actual meaning of the data being combined may not have the same meaning. Differences in the meanings may not be recognized by the parties involved while the results of analyses using the data produce counter-intuitive results leading to unnecessary disagreements. Thus a definitional problem may cause the political process to solve what would otherwise be a technical problem.

2. As the use of management system data becomes more widespread through an agency or more important to decision-making, the need for accurate and complete data becomes more apparent. For example, when the Oregon DOT used bridge management system data as the basis for determining bridge projects, regional inspectors and engineers became acutely aware of the importance of the integrity of the data.

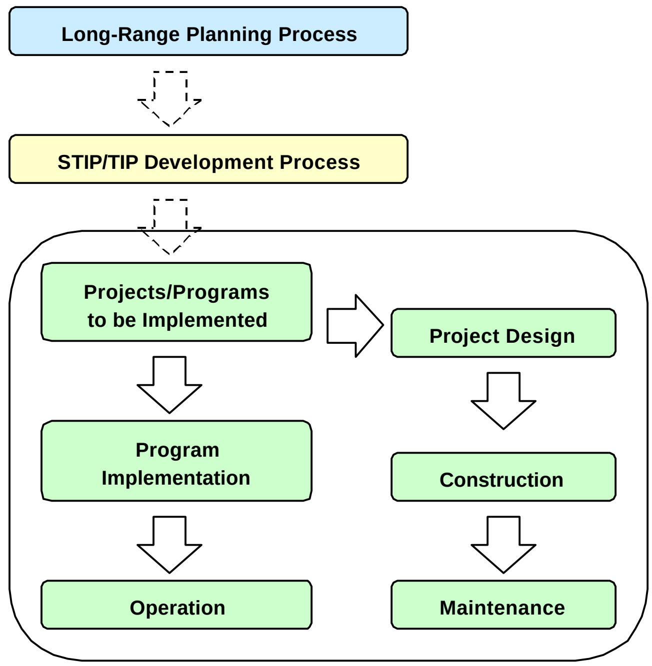
3. Tools or measures to determine policy or performance are easier to develop and integrate into transportation business practices if they are developed for cross-functional purposes. For example, bridge engineers have historically provided bridge condition information in a technical format. This was insufficient for managers to understand the economic implications and did not enable them to make appropriate policy decisions.

BMS under Pontis has evolved as a valuable tool for organizing both quantitative (or more technical) data and subjective information in a way that is useful for program decision-making. As states gain experience with BMS implementation, it has become increasingly clear that a primary benefit of the system is improved communication: inspectors, engineers, planners, programmers, budget analysts, and managers all gain a better understanding of physical condition and performance, funding needs, project scope and cost, policies, and transportation system performance. As a structured method for negotiating a specific program of projects, the STIP/TIP process can be a major beneficiary of this improved communication.

4. As transportation funding in the public arena becomes more and more flexible at the state and local level, competition for that funding will undoubtedly increase. Decision makers faced with a plethora of needs for funding usually look to objective information to substantiate these public expenditures. As requests for projects pour in, those armed with credible and objective data are often at a considerable advantage. Infrastructure management system tools have become very powerful, making sophisticated projections of deterioration and complex benefit/cost calculations that can prove to decision makers that their money will be well spent.

However, agencies must not make decisions about the infrastructure in a vacuum of information about other parts of the transportation system. The technology and professional knowledge exist today allowing agencies to make proactive tradeoffs among various components of the transportation system for overall balance. This balance should be vigorously pursued by management system professionals.

2.3 PROGRAM IMPLEMENTATION, MAINTENANCE, AND OPERATIONS



As projects and programs reach their implementation phase, decision-making tends to have a shorter time-frame and becomes more narrowly focused. Nevertheless, a systems approach to implementation activities, assisted by management systems, can have great value in helping to improve the operational decisions that are made.

The strategies chosen in response to transportation needs can be loosely categorized in two groups:

- Operational strategies, often referred to as Transportation System Management; and
- Capital strategies, such as new construction or functional improvements.

The tradeoffs between these categories are normally evaluated during the STIP/TIP process, where the broad outlines of the strategies are defined. At the same time, both types of strategies have a tradeoff to be considered between start-up costs (program implementation, or design and construction) and on-going costs (operations and maintenance). Although these decisions are made before the implementation phase begins, they rely heavily on experience and metrics that can be captured during implementation. An effective system of recording actual work accomplishments and operational decisions can become an essential element of an organizational memory, allowing the agency to become increasingly competent in its STIP/TIP decision-making over time.

The systems aspect of implementation and operational decision-making is evident in several ways:

- Operational decisions made at one location affect other locations. Examples include traffic signal timing and maintenance scheduling.
- The existence of substantial fixed costs introduces economies of scale. For example, the existence of a construction traffic control scheme for a

pavement project may make it more attractive to take care of other needs, such as safety improvements and bridge work, at the same time at that location.

- Application of consistent standards for the design of both capital facilities and operational strategies, tends to adjust driver expectations, which in turn tends to reduce safety and maintenance problems.

Several useful tools, discussed in the following sections, can help to achieve the benefits of a systems perspective.

Tools for project and program implementation, maintenance, and operations:

Design tools and standards
Secondary needs identification
Resource allocation and scheduling
Monitoring
Traffic management systems
Intelligent transportation systems

Design tools and standards

Based on the observed performance, in terms of operations and maintenance, of existing facilities and programs, agencies can compare different design parameters and develop, over time, useful guidance on how to adapt an optimal design to various local conditions. When this experience is codified into design standards, it can be applied consistently to new projects. Such consistency yields higher-quality work from less experienced designers, saves construction costs because contractors are familiar with the standards, and makes the transportation system easier for its users. Automated design tools further reinforce the standards by making it easy for designers to follow the standards and hard for them not to do so.

Florida DOT conducted a statewide effort to collect and synthesize the experience of its independent transit operators to develop design standards for transit vehicles. A statewide package of specifications was prepared, and in 1996 200 vehicles were purchased.

AASHTO has long been a leader in the development of national design standards for bridges. Now the organization is developing a bridge design package, called Opis, to make it easier for designers to take advantage of the latest standards. Since the design of Opis was based on a full-system approach recognizing the maintenance and operational business processes surrounding bridge design, it will be able to interface with Pontis and other outside systems and exploit the synergy that these interfaces provide.

Secondary needs identification

As a part of project design, many agencies routinely take a look at all types of needs at the same location, to determine whether additional work should be added to take advantage of mobilization and traffic control measures already in place. Management systems, especially when they have a mapping or GIS capability, can make this process simple, especially when needs can be forecast for the near future, that might not be obvious at present. Once this capability is well-developed for project design, it is apparent that it can be even more valuable during the STIP/TIP process. Identifying secondary needs earlier means that there is less "scope creep" exhibited in the STIP/TIP projects, since the cost estimate becomes more comprehensive from the start.

Colorado maintains a geographic database of accident statistics that is readily available to the designers of pavement projects. Designers can use this information to identify opportunities to include safety improvements in the scope of their projects.

Missouri, like Colorado, maintains a safety database that is closely interfaced with a facility inventory and condition data. Using a GIS tool, an engineer can readily overlay safety statistics on project locations to diagnose safety problems and determine whether safety improvements should be investigated as a part of project design.

Resource allocation and scheduling

An important part of maintenance and operations management is deploying agency resources so that they achieve the greatest effectiveness. When management systems provide a balanced view of needs across an entire geographic area and across all types of activities, managers have superior information and flexibility in their deployment decisions. Even greater benefit can be achieved when managers have information about the needs and deployment of neighboring maintenance areas, because this makes it possible to barter or transfer resources to where they can be used most efficiently. Similarly, accurate knowledge of crew and equipment locations on an hourly or real-time basis, makes it more feasible for crews to tackle multiple types of needs at the same location, as well as making the agency more effective overall in incident management.

The Road Administration of Finland developed a resource allocation tool for maintenance, which evaluates the road user benefits of shifting funds among maintenance categories and geographic areas. Road user benefits were determined by means of a statistical study of the results of a user survey, asking users to state their preferences from among carefully chosen levels of service for snow removal, mowing, rest area cleanliness, and other common maintenance concerns.

Monitoring

The organizational memory which makes it possible for agencies to develop reliable planning models and design standards, can exist only if there is a systematic program to capture data on maintenance work accomplishments and operational incidents. These data must include the identification and quantification of the resources used, and the locations or facilities worked upon. Unfortunately, this need has gone largely unmet in management system implementation efforts, both because it does not produce immediate management system information, and because it involves organizational units and procedures that are not organized according to the ISTEA six-

Missouri DOT captures operational and condition information in a form which can be analyzed in its Geographic Information System. The graphic display of such data, particularly the overlay of data from diverse sources, makes it easy to diagnose problems and identify actions that might not otherwise be evident.

Florida DOT maintains a database of transit vehicle characteristics, which it can relate to data on vehicle performance over time. This information is valuable for further improvement of the specifications in the future.

system taxonomy. A more comprehensive approach to management system development can recognize the important role that maintenance and operational units have in the long-term success of all parts of the decision process.

Traffic management systems

Many city governments have systems of coordinated traffic signals. With the increasing awareness of interagency cooperation and networked information systems, it is becoming increasingly common for coordinated networks to extend to multiple jurisdictions within counties and metropolitan areas. Agencies that take an active role in monitoring and fine-tuning their traffic management systems can achieve substantial mobility and air quality benefits.

> Via cooperative agreements among the City of Tucson, Pima County and the Arizona Department of Transportation, the Tucson metropolitan area has a single, coordinated traffic signal program, involving the operation of 350 signalized intersections. These are controlled through a computerized traffic management system. Several timing plans are utilized based upon an estimated travel speed, depending upon traffic conditions, time of day, day of week and other factors. The goal is to maximize the efficiency of the roadway system through the selection of signal timing cycles and progressions.

Intelligent transportation systems

In recent years, major research and deployment efforts have been conducted to find new ways in which information technology can improve the operation of specific parts of the transportation system. Even if advanced technologies are not soon deployed across the entire network, still the interconnectedness of the transportation system means that ITS improvements on one facility can have secondary benefits to other facilities, providing much-needed alternatives to capacity expansion.

> The term "Intelligent Transportation Systems" refers to a large collection of related services that exploit new information technology. Here are some examples:
>
> - Automated traveler information
> - Emissions testing and mitigation
> - Ride-matching and reservations
> - Personalized public transit
> - Electronic payment services
> - Commercial vehicle electronic clearance
> - Emergency notification and personal security
> - Emergency vehicle management
> - Collision avoidance systems
> - Pre-crash restraint deployment
> - Automated highway system

Findings

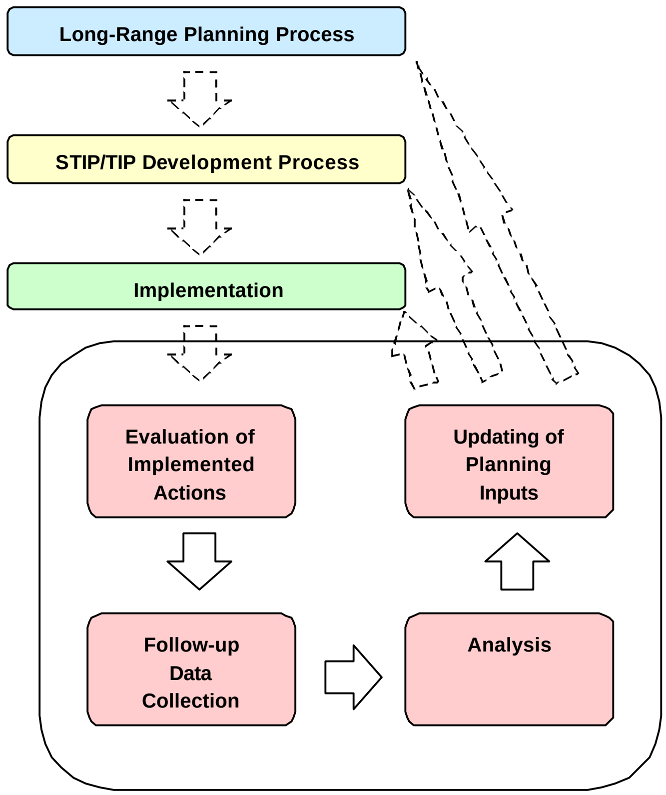
1. The planning capabilities of management systems are inextricably linked to the processes of project and program implementation, maintenance, and operations. All of these areas benefit in similar ways from a more comprehensive approach to management systems. Work accomplishment and incident data that can only be captured at the maintenance and operations level of the organization, are essential to the long-term credibility of the planning models in management systems.

2. Transportation agencies have made substantial progress on the implementation of traffic management systems for signal coordination, and are on the verge of additional success in the field of Intelligent Transportation Systems.

3. Agencies with GIS capability have found it to be a valuable tool for identifying secondary needs as a part of project design. Some of these agencies have succeeded in transferring this capability also to the STIP/TIP process to enable more accurate early scoping of projects.

4. Resource allocation tools for maintenance and operations management have many of the same features and characteristics as the project selection and prioritization tools used in the STIP/TIP process. Recognition of this similarity may facilitate implementation of this capability in more agencies in the US.

2.4 EVALUATION OF IMPLEMENTED ACTIONS



The philosophy of continuous improvement can readily be extended to management systems, manifesting itself in a feedback loop where the planning process outputs are compared to real-life outcomes, with planning inputs adjusted accordingly. The purpose is to make planning models more realistic, so future outcomes will be closer to what was intended.

In order for this feedback loop to work, the agency must have an effective system of recording work accomplishments which documents and quantifies the exact actions which were taken, the resources which were used, and the exact inventory items (facilities, vehicles, market segments, etc.) which were acted upon. This need was discussed in the previous section.

In addition, the agency must have an ongoing process of monitoring system condition and performance. This is the same data collection activity that was discussed in the context of long-range planning and STIP/TIP development, repeated on a regular basis in a consistent way so before-and-after comparisons are possible.

With this information, the agency can analyze its own experience to find the places where the planning outputs were not achieved, with special attention focused on the predictive capabilities. When discrepancies are found, they may result from any of several factors:

- Errors in quantitative model parameters, such as deterioration rates, growth forecasts, unit costs, or action effectiveness
- Failure of the planning models to consider factors that turned out to be important
- Incorrect assumptions made in the planning process

- Unforeseen events

By actively diagnosing the discrepancies which are found, the agency can update and improve its decision-making process over time.

Inventory, performance measures, and monitoring

Tools for evaluation of implemented actions:

Inventory, performance measures, and monitoring
Updating the State-of-the-System Report
Statistical updating of model parameters
Stakeholder survey

The feedback loop relies on a stable inventory system, allowing the facilities, equipment, and other inventory items to be tracked over time. For physical assets, it is very important to have a stable referencing system, which may include geographic location and/or permanent identification numbers. The calculation of performance measures should also be reasonably stable over time. Collection of condition and performance data should occur on a predictable and consistent basis, using repeatable objective procedures.

The Pima Association of Governments set out to employ a traffic management strategy to improve the performance of a congested intersection. In order to judge the effectiveness of the action and its applicability to other intersections, the agency conducted before-and-after measurements of several indicators: daily traffic volume, vehicle occupancy, vehicle delay, and pollutant emissions.

Oregon DOT monitors the performance of its congestion management plan by tracking several systemwide performance measures over time, including peak volume/capacity ratio, traffic level-of-service, peak hour traffic speed, mode split, person throughput, and travel time by mode. The agency also uses volume/capacity ratios to track the performance of intermodal facilities.

Colorado DOT has prepared a proposal to the FHWA to reduce the number of bridges inspected annually by about 25 percent. This would be done by lengthening the inspection cycle from the current, mandated 2-year interval to 4 years for selected bridges for which the BMS demonstrates that this longer inspection interval will not affect the quality of data on the safety or structural integrity of the system

Updating of the State-of-the-System Report

For most users of planning information, the credibility of the decision-making process in the long run will be judged by comparing the State-of-the-System Report with previous versions of the same report and with planning forecasts. More than any other tool, the State-of-the-System Report can be a catalyst for broad changes in policy direction as the systemwide results of earlier policies become apparent. Since the data in this report are highly summarized and can mask important underlying causal effects, it is important that the report also include analysis

Colorado DOT used its State-of-the-System Report to guide a multi-year program to improve statewide pavement condition. In the first two years of the program, pavement condition differed substantially from forecasts, leading the agency to revamp its deterioration models. Later in the program, the report showed pavement conditions reaching the agency goal for the network as a whole, but not for the interstate highway system. This led the agency to reallocate funding to that part of the network. Subsequent reports showed that the goals were finally satisfied in all parts of the system.

and commentary on the factors that have led to important changes from previous reports or from forecasts.

Statistical updating of model parameters

When a reasonably rigorous data collection program is in place and solid quantitative prediction models are used, it becomes feasible in principle to apply statistical methods to the data to improve the model parameters. In a few cases, management systems have included automatic updating procedures internally. This is possible when a complete historical database is available, or when the mathematical form of the predictive models allows relatively simple updating methods such as Bayesian updating. Often, as in the case of travel demand models, automatic updating may not be feasible, but it still may be valuable to conduct periodic special studies to update the models. It is often valuable to conduct such studies on a regional or national scale, as is done in pavement and bridge engineering, and in public transit performance modeling.

> AASHTO's bridge software products Pontis (for bridge management) and Opis (for bridge design) have been designed and developed independently for different sets of users. However, the information on deterioration and life cycle costs collected in Pontis is potentially valuable for evaluating and improving bridge design standards used in Opis. Opis, therefore, includes as one of its planned features, the ability to track life cycle costs of various design types under various conditions, and use this feature to keep designers informed of the predicted performance of their designs. Over time, this should lead to more durable bridges.

> Florida DOT tracks maintenance work accomplishments by activity and location in its Maintenance Management System. In one recent episode, the agency's data showed that the cost of sand removal on a particular waterfront road was much larger than expected, enough so that the agency was able to justify construction of a wall to keep blowing sand from building up on the road.

Stakeholder survey

For decision topics where the key performance measures include subjective customer or stakeholder satisfaction, it is useful to conduct periodic stakeholder surveys. These surveys can monitor both the effectiveness of actions, but can also be designed to pick up long-term changes in customer expectations that may affect future priorities.

> Oregon DOT has proposed the use of a stakeholder survey to evaluate its Intermodal Management System. Possible topics to be addressed by carriers and shippers include: door-to-door travel time, quality of the roadway, service quality, quality of delivery, and overall ease of doing business.

Findings

1. A feedback loop of evaluating and updating the decision-making process is essential to establishing its credibility and improving it over time. The data collection required for this the same as what is needed for long-range planning and STIP/TIP development, and has the same considerations regarding integration.

2. In some cases, a complete analysis of data collection needs can lead to a reduction of data requirements, as evidenced by Colorado's experience with bridge inspections.

3. The State-of-the-System report needs to be updated each year so decisionmakers and the public can see whether the desired systemwide changes have been achieved.

4. Few agencies have enough experience with management systems to have exploited the feedback loop on a systemwide basis so far, but some excellent tools are available when organizations are ready to use them.

5. For more subjective performance measures, periodic stakeholder surveys can help to evaluate decision outcomes from the customer standpoint.

Part 3. Special Topics

It is evident from the preceding sections, that the thought process which goes into integration of management systems with the decision-making process (vertical integration), also leads naturally to integration among the systems (horizontal integration). This could be considered a top-down perspective on integration.

Interestingly, though, much of the work on management systems to-date has been more bottom-up, focusing on horizontal integration directly, without first addressing the integration of the decision-making process from an agency-wide perspective. This is understandable, because the horizontal work done to-date has dealt mainly with technological change, which is much easier and faster than organizational change.

The following sections describe some of the more technological work that has been done on the development of integrated inventories and performance measures.

3.1 DATA COLLECTION EFFICIENCIES

Inefficiency and duplication in data collection has existed since long before ISTEA, largely because it is often difficult for separate organizational units needing the same data to come to agreement on standards for data quality, coverage, definitions, and timeliness. Since organizations change regularly, there is always the possibility that a cooperative data collection agreement will come apart when there is a change in the responsibilities or requirements of one of the partners. ISTEA only exacerbated this problem by establishing different data requirements for different parts of the overall decision-making process.

Missouri DOT is not collecting any new data today as a result of ISTEA. In fact, the agency is seeking to delete some of the data that are currently collected.

Taking a more systemic view, however, it can be recognized that the data requirements of a transportation agency as a whole change much more slowly than the requirements of its individual organizational units. For example, the responsibility for collecting traffic counts, and the uses to which the traffic count data may be applied, tend to change regularly. However, in the long run it is a sure bet that the agency will always need traffic counts, and that the overall requirements for frequency and coverage will change only very slowly.

Recognizing this fact, transportation agencies can focus attention on systemwide data collection and management processes, achieving both efficiency and stability. Accomplishing this type of organizational change is difficult by itself, but this is an area where technological change has often been effective as a catalyst for organizational change. Technologies that have been successful include:

Corporate databases. Though often feared as the 1990s version of the imperious mainframe shop, corporate databases can be an effective means of data-sharing if managed with a light touch, facilitating negotiation of data quality standards rather than imposing undue restrictions on data users. The wide range of experiences of the states with corporate databases attests to the importance of management style in their success.

Geographic information systems. It is not at all unusual for two different organizational units to perform similar data collection activities in the same location, unknown to each other. For example, many police agencies collect auto occupancy data as a part of accident reports, which data can easily duplicate roadside surveys. The advent of statewide geographic information systems has made it much easier for data users to find unexpected sources of data, thus lowering or eliminating their own data costs.

Automated data collection equipment. When data collection processes require expensive equipment, it makes sense to look for other types of data which could be collected by the same equipment at the same time, at low marginal cost. A particularly successful application of this thinking is the use of pavement survey vehicles to collect data for sign inventories, landscape planning, snow removal, travel times, and clearances.

Colorado DOT has adopted a "one pass" data collection program, using a private vendor van for standard pavement data (roughness, cracking and rutting), skid resistance, road geometrics, ROW video of roadside obstacles, photo logs, signing inventory, shoulder conditions and environmental conditions. Benefits of the program include cost savings due to consolidation of efforts; improved safety for field staff who normally collect data; pictorial (historical) video reference; accuracy to +/- 0.1%; frequency of data collection can vary while maintaining a stable work force.

In the long-run, **Intelligent Transportation Systems** also promise to be a rich source of operational data.

Even without advanced technology, transportation agencies have untapped data collection resources which can be exploited. For example, every day during peak hours, thousands of agency employees travel typical commuter routes in their journeys to and from work. This deployment of potential data collection staff could be a valuable source of travel time data.

3.2 COMMON REFERENCING SYSTEMS

Data used in the management systems can come from many different sources and in many different forms, such as point data, lines, surfaces, or volumes. But all data describing real world features must have an "address" to a physical location. Because most data are addressed to meet the needs of specific applications, most transportation agencies support multiple referencing methods, such as reference point plus distance, county route log, state plane coordinates, route/milepost, or stationing.

Management system applications within a transportation agency share the need for "core" data (e.g., traffic volumes) which must be shared widely, while maintaining other "unique" data (e.g., girder type) whose sharing requirements are more limited. In order for sharing of core data to be efficient, data from different sources addressed to the same physical point or along the same linear segment must have a means of coordinated addressing, so that the software can recognize that two objects are near each other. Without a mechanism for relating multiple or different methods to the same physical location, the business of data management can be tremendously inefficient, resulting in redundant data collection, an emphasis on data manipulation instead of data analysis, and the abandonment of otherwise fruitful efforts for utilizing data for multiple purposes.

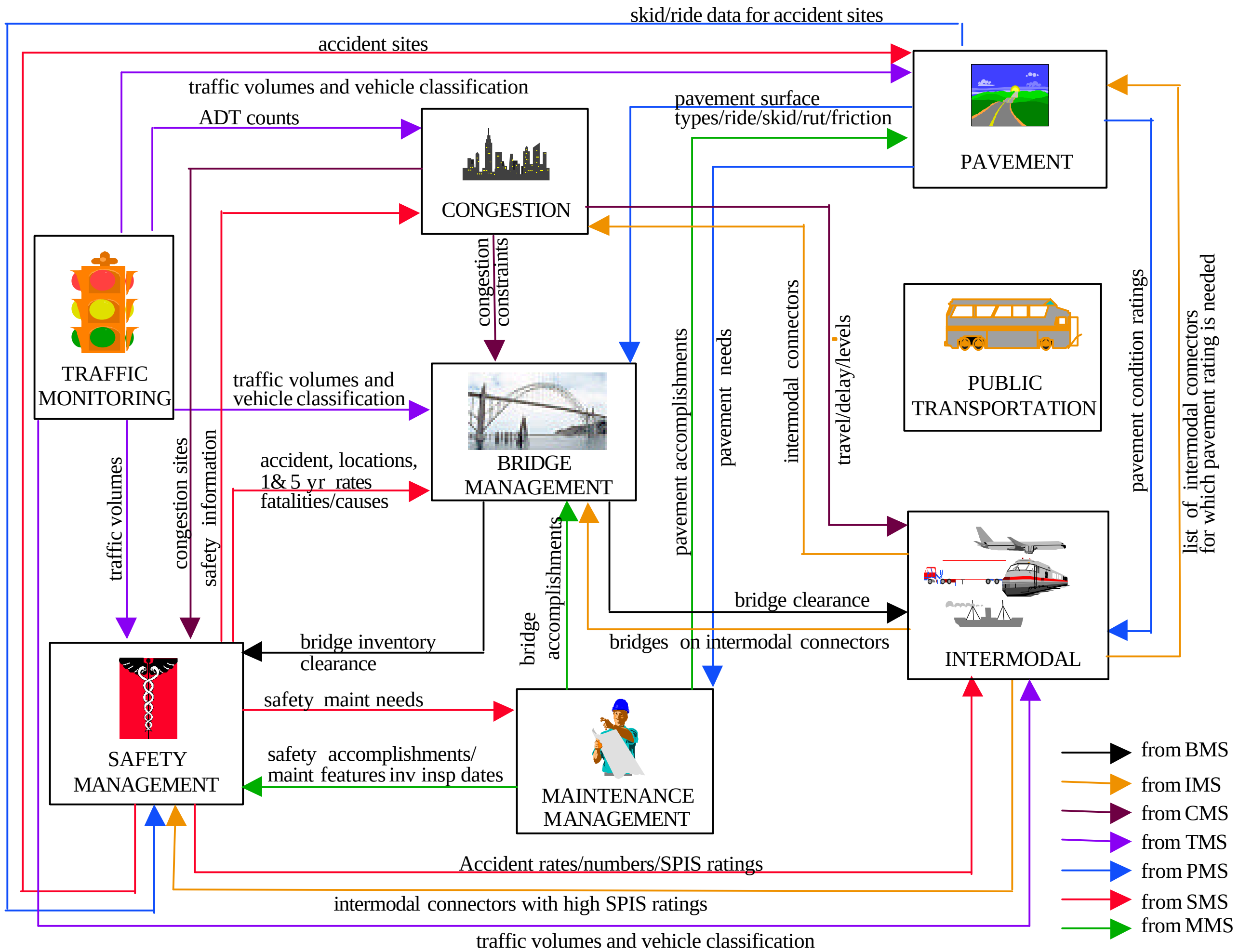
Common Referencing Systems are needed to:

- Interrelate data;
- Economize on data collection and data manipulation;
- Share data electronically;
- Display the interrelationship of data accurately via GIS platforms; and,
- Facilitate the synthesis of data for more informed decisions about a particular action.

Many transportation agencies and national research efforts are addressing this issue of relating multiple referencing methods. GIS can be credited with bringing the issue to the forefront because the visual display made apparent the inherent problems of unrelated referencing methods. The users of the various data already collected in a transportation agency often have very legitimate reasons for choosing the referencing methods that they use. For example, crash databases normally permit the detailed description of locations in and near intersections, since those are where most crashes occur. Pavement management systems, on the other hand, organize their referencing around road segments delineated by changes in pavement design or width.

Although many agencies actively try to reduce the number of referencing methods that they use, it has proven most effective to allow multiple methods to remain in use, and to establish a master enterprise-wide system for converting among these methods. In a corporate database environment, it is often possible to offer a centralized service, available to all data users, to express any data item in terms of any supported referencing method, including any required averaging and summarization.

The following diagram, from Oregon DOT, demonstrates the intricacy of data sharing requirements among management systems, showing many places where common referencing systems would be important.



This makes it possible, for example, to write software to correlate crash occurrences with pavement skid and rutting data without the programmer having to know that the data were collected using three different referencing methods.

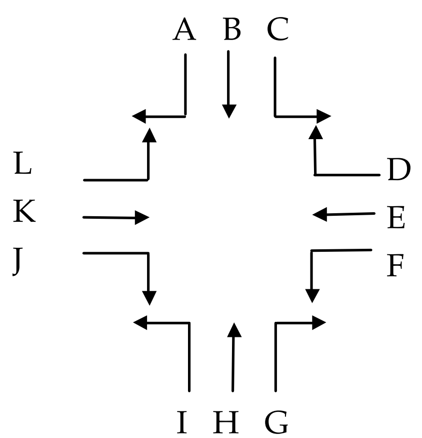
Although the establishment of a common referencing system is a time-consuming technical task, in practice the most difficult aspect of it has been organizational. Often the users of similar referencing systems must be asked to reconcile the differences among their systems, and often additional data collection is required to resolve ambiguities. For example, bridge management systems have for years been satisfied with locating bridges by their latitude and longitude, and by the route/milepost of the roadway passing over the bridge. Since bridge location data were seldom used, accuracy was allowed to suffer. Construction of a common referencing system requires that considerable time be spent to clean up the location data so bridge references can be correlated with highway network references. A possible reward for accomplishing this task is that it becomes possible to use the bridge data in applications for routing oversize/overweight loads.

When agencies embark on the construction of common referencing systems, most of the attention is typically devoted to linear features such as road segments. This is sensible given the importance of linear features in a transportation network. Several other types of referencing are also valuable to support, however:

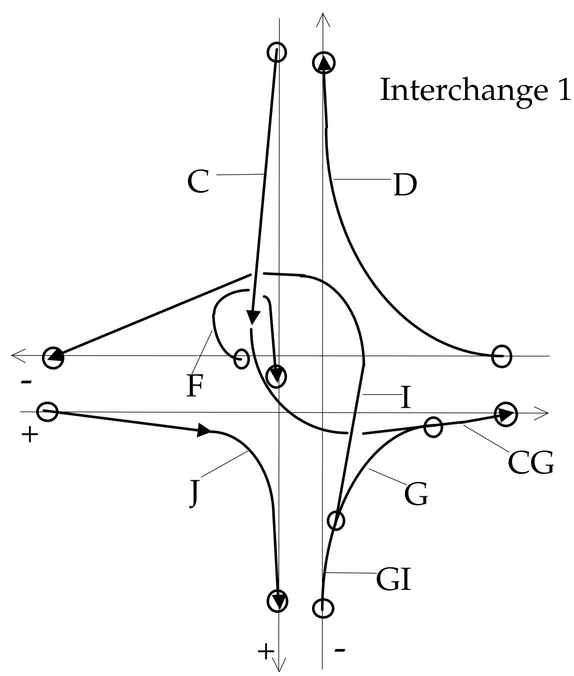
- Area referencing, such as the ability to identify a feature with a county or district.
- Point referencing, such as locating a rest area or maintenance facility.
- Temporal referencing, such as identifying a stream of data over time with a specific Federal, state, or local fiscal year. A related problem in

Because the Colorado DOT has not had a formal method for referencing interchange ramps, a half-dozen custom methods have been developed by the program areas needing to track activities occurring on ramps. The lack of a formal method has kept ramp data from being tracked and has prevented electronic sharing of any ramp data. A task force of primary stakeholders was formed to develop a formal ramp referencing method. In order to emerge with a single method that would address the needs of multiple programs, all parties had to buy into the value offered by a single method for improved information sharing and accept changes to their existing processes.

The system that was finally agreed upon features the unique identification of twelve basic intersection movements as well as double-functioning segments (such as GI and CG) so that even when applied to very complex interchanges, all segments should have a unique code.



Segment/Ramp Coding Methodology



Coding Applied to Segments

budgeting and in the analysis of past cost data, is assigning appropriate inflation factors to economic data.

- Organizational referencing, such as assigning an expenditure to appropriate organizational units and cost categories for accounting, budgeting, and programming.
- Activity referencing, such as assigning a specific maintenance work task to action types appropriate for accounting, work order processing, maintenance planning, and programming; and assigning it to the proper project, contract, and/or work order number.

All of these referencing problems can be addressed with similar approaches of consensus-building and clear assignment of long-term responsibility for maintaining the system.

3.3 PERFORMANCE MEASURES

The ISTEA focus on system performance and intermodalism has created a substantial professional interest in a new planning concept called "performance-based planning," and in identifying performance measures that are truly multimodal. This trend is pushing transportation agencies to expand beyond the traditional measures regarding the performance of the transportation facility to those that are intermodal and concerned with the purpose of the transportation system.

The business of measuring performance is complicated by the objectives sought. For example, "performance" can be viewed from the project or system level, from localized or national interests, and from the system manager's or customer's perspective. While measurement from any of these perspectives is valid, a transportation agency must determine what objectives it is trying to achieve when selecting measures, for the measures will drive data requirements and the information available for the decision making process.

> Transportation agencies that develop performance measures in a systemwide top-down fashion, starting with transportation values or goals, tend to reach very similar results that apply equally well to all the ISTEA management systems.

So far in the history of management systems, the bottom-up way in which these systems have been designed has led to a focus on the performance of individual constructed facilities. For engineering decision-making, this focus is useful and is readily grounded in objective data and analysis.

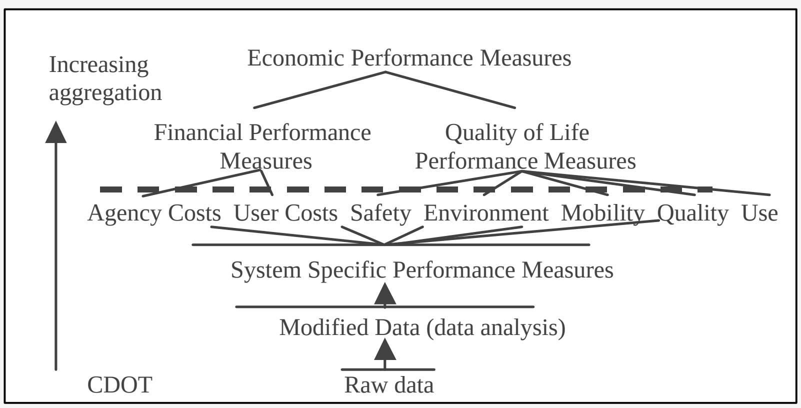
However, when the focus changes to emphasize overall system performance for the traveler or society, as is necessary to evaluate decisions which may change the composition, extent, or modality of the transportation system, a bottom-up perspective is not very useful. As the following case studies demonstrate, many states have adopted a top-down approach that begins with a complete list of transportation values, and derives from this a balanced list of objectives and performance measures. Such a framework still requires engineering data and objective analysis whenever these are available, but it also makes room for subjective tradeoffs and, in fact, helps to focus the judgmental decisions that must be made. The case studies illustrate two striking observations:

- Transportation agencies that have independently adopted the top-down approach to identification of performance measures, have largely ended up with the same or very similar results.

- Each of the ISTEA management systems could readily calculate the effects of decisions on several of the measures, if they were designed to do so. In particular, the outputs of asset-oriented systems such as pavement and bridge management systems fit within this framework just as well as the mobility-oriented systems do.

The first observation suggests that the potential for joint development of decision-support tools should be very high, if done from the starting point of a list of values that all transportation agencies share. The second observation suggests that a top-down approach to the definition of these tools based on systemwide values and performance measures, would be far more effective and efficient than the balkanized approach, unintentionally reinforced by ISTEA, of separate development of the same decision support tools for each separate type of facility.

Colorado DOT identified seven categories of systemwide transportation values, which provided a framework for organizing more detailed performance measures.



The San Francisco Bay Area Metropolitan Transportation Commission identified performance measures specifically for mobility, including: travel time, variability of travel time, and congestion (level of service).

The Pima Association of Governments identified the following performance measures: travel time (vehicle delay), congestion (volume/capacity ratio and level-of-service), transit load factor, and transit frequency.

Oregon DOT identified the following agency goals and performance measures in response to each goal:

- **Accessibility/Mobility:** Congested mileage, commuter travel time, percentage of non-SOV commuters, public transit coverage, bicycle lane and sidewalk coverage
- **Land use:** VMT per capita
- **Safety:** Vehicular death and injury rate
- **Infrastructure Preservation:** Facility condition
- **Public Involvement:** Public satisfaction with their level of involvement
- **Finance:** Funding as a percent of needs, allocation of funding according to vehicle cost responsibility
- **Air quality:** Population within air quality standards
- **Aesthetic Values – Tourism:** Miles of scenic byways
- **Planning:** Percent of governments with transportation system plans