Monitoring System Performance: A Foundation for TSM Planning

Michael D. Meyer, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge

Transportation planning processes have long placed strong emphasis on the collection of data for the determination of the existing conditions on the transportation network. Since enactment of the Federal-Aid Highway Act of 1962, and the resulting development of the comprehensive, continuing, and cooperative ('3C') process, a continuous feedback of network performance and demographic information has been required. The concept of monitoring is thus not new to the field. However, because of the increased focus on operations planning and the increased willingness by many communities to consider transportation system management (TSM) actions, monitoring has become even more important. This importance derives from the need to determine the success or failure of a specific transportation action in a short time.

This paper examines the role that monitoring has (and should have) in TSM planning. Specifically, the paper addresses the following questions:

1. What is monitoring and how useful is it for TSM planning?
2. Can a regional TSM program be effectively monitored and evaluated given that most TSM actions are directed toward alleviating extremely localized problems?
3. How can the results of implemented TSM actions be determined, monitored, and reported?
4. Who should do this monitoring?
5. How can a TSM action that has been implemented be evaluated against improved transportation system performance?
6. And, finally, how should the monitoring procedures be tailored to the size of the particular urban area?

FOCUS OF CURRENT MONITORING PROCEDURES

The concept of collecting information on system performance or conducting a before-and-after study of a particular action is not new to the transportation field. The U.S. Department of Transportation (DOT) and many state departments of transportation have for many years required the collection of data on the performance of the highway network, the most important of which is vehicle kilometers of travel (1,2). More recently, DOT has initiated several programs aimed at establishing a unified reporting system for data on transit performance (43 Federal Register 58 928-58 944). Such data as bus fleet age distribution, bus revenue vehicle kilometers, bus revenue seat kilometers, and bus route kilometers are to be collected from each urbanized area so that federal funds can be distributed by need and performance characteristics.

At the regional and local levels, monitoring procedures have typically been used to collect information on travel trends and to provide input into the processes by which decisions are made on the long-range level of investment in transportation. Transportation studies that focus on long-range concerns do in fact require extensive sets of primary and secondary data. Most certainly, however, some of the information needed for long-range planning and the techniques used to collect it are different from that required for TSM planning (3,4).

In the past, monitoring of TSM-type actions has been conducted only on an occasional basis and then only to satisfy specific requirements. Data have usually been gathered on location-specific problems and have had limited value in developing valid regional estimates of the effectiveness of TSM actions. The data base needed for examining the impacts of TSM strategies on a regional basis has thus been, in most cases, not available.

Recently, efforts have been made to develop regional travel monitoring procedures that can be used to complement the more extensive traffic-counting programs used to monitor changes in vehicular flows. These procedures focus on specific measures that can be estimated from field data at a relatively low cost and can supposedly be used to assess (at a regional scale) the overall effectiveness of a TSM program (5,6). These measures are related to several categories of need, such as evaluating the effectiveness of TSM actions, monitoring changes in air quality indices, determining the energy efficiency of travel, and following the general trends in transportation characteristics. As can be seen from this list of needs, the monitoring procedures are designed not only to inform the TSM process, but also to address other concerns in the regional transportation planning process.

The need to monitor transportation system performance has thus been recognized ever since the transportation planning process was formally created. The procedures that have been developed to satisfy this need and the type of information gathered in the monitoring process, however, have not been particularly useful for TSM planning. Most of the data-gathering activities that do collect information useful for TSM planning are extremely limited in scope, in both a geographical and a functional sense. Although some efforts are now being made to develop procedures for evaluating the effectiveness of regional TSM programs, the question need not be asked whether such efforts can, given the localized nature and relatively small effects of most TSM actions, ever succeed in reaching such judgments.

ROLE OF MONITORING IN TSM PLANNING

Initial responses to the requirements of the TSM planning regulation were problematic. However, one of the first steps taken by most regional planners was to establish some sort of mechanism to monitor the performance of TSM actions and, in some cases, the process used to develop the TSM plan. The reasons for such monitoring activities were many. External to the TSM planning process itself, it makes sense to monitor both the physical installation of actions and their performance in altering the transportation system once installed. The first of these is (7)

a way of measuring the product of service oriented planning, the second a form for supplying feedback on the effectiveness of decisions taken. It is also important to monitor the process itself, including the design of actions, the installation of new relevant skills and resources in the participating agencies, the evaluation of actions proposed and the preparation of the necessary reports.

That monitoring became an important component of TSM planning should not be much of a surprise. In addi-
tion to its obvious contribution to any planning process, monitoring also represents the mildest form of process development in a logical place to start, particularly if more vigorous measures are obstructed. Given that the regulations require that reasonable progress be shown in the development of TSM projects, monitoring procedures can also be reasonably considered an implicit requirement of the TSM regulation. Furthermore, in an institutional environment where metropolitan area organizations have, in some cases, been hesitant to promote TSM vigorously, monitoring activities provide the most practical means to adjust quietly to modes of working together while avoiding the problems of establishing a formal, methodologic approach.

As the TSM process evolved, the role that monitoring had in it was slightly modified to reflect the changing characteristics of TSM planning itself. In most cities, some form of monitoring has been conducted that reflects the needs of the TSM process and the characteristics of the urban area. In larger cities, for example, monitoring strategies are usually based on the principle that it is not necessary to monitor every TSM project. In these cities, where the number of TSM-type actions could range into the hundreds or even thousands, existing resources do not permit detailed monitoring or evaluation of each TSM improvement (6). Small to medium-sized cities have continued their ongoing efforts to collect data on TSM programs, projects, and activities, with these efforts of course dependent on available resources. In all cases, however, it is agreed that monitoring activities are especially necessary when innovative TSM strategies are being implemented.

In preparation for this paper, letters were sent to TSM (usually metropolitan planning organization (MPO)) planners in 30 cities in all geographic areas of the country and representing different city sizes. In general, the importance of monitoring is recognized by most planners, although the stages of development vary considerably, as is illustrated in the following statements:

We will be placing additional emphasis on monitoring project implementation and effectiveness. The latter is particularly crucial, we feel, given the relatively non-traditional nature of many TSM improvements, as well as the new demands (e.g., for air quality improvement) placed on more established efforts such as signal synchronization projects.

Monitoring the performance of transportation operating agencies is the heart of an effective TSM process. Without an operating feedback mechanism, we have no means to determine how effective proposed TSM projects will be in achieving objectives. We have instituted two processes: performance auditing and standardized reporting systems for transit operators. This information is the basis for evaluating the system-wide effectiveness of TSM efforts.

Specific projects developed with Federal funding support usually are closely monitored. Funding support at the metropolitan level for data collection and monitoring is somewhat more difficult to realize. The many demands the Federal Government has placed on MPO's to satisfy planning requirements has made it difficult to allocate the needed resources to system performance monitoring.

I would tend to view this[s system monitoring] as an integral element of any urbanized area's transportation planning process. The inclusion of system monitoring as a "TSM procedure" is open to some discussion. The more critical question, however, is whether an urbanized area has "in place" a mechanism for evaluating both overall system performance and the more specific advantages and disadvantages of new and innovative techniques. [Our] monitoring program consists mainly of traffic counts....

The issue of system monitoring has been on the minds of all the transportation planners involved in TSM. Two things seem to get in the way: one is staff limitations. Only in the past two years has TSM been assigned the operating responsibility (the first-year TSM was prepared by an ad hoc Task Force). Staff assigned to TSM have added that to their other responsibilities, rather than as a full-time duty. The second problem is state of the art. Good monitoring and evaluation techniques are not always available and where they are, often involve extensive data collection (surveys, counts, etc.). This data collection is often much more costly than implementation of the original project and cannot be justified to department decision-makers.

In essence, these statements are saying that monitoring is an important component of TSM planning, especially for innovative projects, but that there are administrative and financial limitations to developing a monitoring program at the scale needed to evaluate a TSM program on a regional basis. This means that any attempt to develop a monitoring program must not only consider the type of technical support data needed but also must keep in mind that these administrative and financial constraints have to be addressed if the program is to be successfully implemented.

What role does monitoring have in TSM planning? There are several functions that a monitoring program should perform in a TSM planning process:

1. Project design and preparation—This is the movement of a specific action from proposal to implementation. It includes preparing a functional design to meet specified objectives, refining it to a detailed design, securing approvals for implementation from appropriate agencies and, with respect to all these steps, arranging for the necessary technical services.

2. Project execution—This is the actual construction of the project or its implementation by a series of official actions. Agency services lent for its continued operation also fall into this category.

3. Project performance—This includes measurements that determine the achievements and impacts of a project, either individually (of special interest for innovative TSM projects) or in combination with others, to determine overall program effects (9-11).

4. System performance—These are measurements that show the condition of the entire transportation system, with special emphasis on conditions affected by TSM actions. These are the background data for TSM planning.

It is of course very easy to say that a monitoring program should be established that addresses both project and system performance but quite another thing to suggest how this is to be accomplished. To do the latter requires a general awareness of the existing system of data collection and the organizational responsibilities for carrying it out. Thus, let us begin by discussing in general terms what monitoring should be.

MONITORING AS A DECISION SUPPORT SYSTEM

In examining any planning process, the most important question, one that must be asked right at the start, is: What type of information is needed to reach a decision? The type of information needed quite clearly depends on the type of decision that is to be made, and the effectiveness of a decision is many times closely related to the comprehensiveness and comprehension of this information. At the project implementation level, the type of decision that occurs includes changing specific characteristics of the project to reflect new conditions or terminating the project because it has not achieved its original purpose. Thus, the performance of a high-occupancy-vehicle (HOV) lane implemented to provide time savings for transit or ride-sharing vehicles should be monitored to see whether it has indeed been successful in reducing travel times. However, if the ultimate objective of such a project is to encourage automobile drivers to change their style of commuting, a survey to determine whether such changes have occurred would...
then be necessary. On the other hand, an HOV lane could be serving its main purpose effectively (as shown in collected data) while at the same time causing serious adverse impacts on the highway system of which the project is a part. An example of this would be an increase in the number of accidents that could be related directly to the project. If monitoring is to be really useful in this case it should be directed toward providing information not only on what is happening (e.g., the increase in the number of accidents) but also on why it is happening (e.g., insufficient physical separation between lanes) so that remedial action can be taken.

At the program and system performance level, the decisions to be made have become less tied to details of specific projects and more related to general indicators of how well we are doing. How to allocate limited resources among a set of transportation programs becomes the overriding issue and, for this decision to be made, information must be available that can illustrate those areas (or efforts to attain regional objectives) where additional resources are needed. Thus, indicators of system performance, e.g., vehicle travel (VT) or transit ridership, are critical.

Information gathering and handling thus has a significant influence on the decision-making process. Presenting too much information, however, is liable to burden the decision makers with too many facts and figures, while insufficient information runs the risk of missing factors that could be crucial to the outcome of the decision (12). Can viewing the monitoring process as a means of supporting decisions provide us with any useful insight as to how monitoring should be done and who should do it? The remainder of this paper will argue that it indeed does.

A focus on information handling and how it affects decision making is largely found in the management literature. Decision support in this context implies the use of computers to (13,14)

1. Assist managers in their decision processes in semistructured tasks;
2. Support, rather than replace, managerial judgment; and
3. Improve the effectiveness, rather than the efficiency, of decision making.

The procedures for decision-support systems are similar to but in some ways distinct from other approaches using management information systems, operations research, and management science. An important distinction is that a decision-support framework characterizes organizational activities in terms of the types and levels of decisions involved, i.e., the same distinction as made above for the development of a monitoring methodology. The information needs for each type of decision differ according to the accuracy of the information: its level of detail; time horizon; frequency of use; and sources, scope, type, and age. Each of these criteria would be a useful variable to consider in the formulation of a monitoring program. For example, decisions on whether TSM actions should be modified or ended require relatively accurate information as compared with longer-range actions in which the decision maker is dealing with uncertainty and often ill-defined variables. Also, because the time horizon for the implementation of TSM actions is so short, the frequency with which the information must be gathered and used is greater than that for the information gathering associated with long-range planning and decision making. A TSM-oriented monitoring program should also rely on a well-defined and narrow set of variables aimed specifically at certain types of actions, whereas the scope of information for long-range planning and decision making would typically be very broad.

A theme developed in the overview paper by Lee and Meyer for this conference provides a useful point of departure in relating TSM planning and decision making to the type of information needed from a monitoring program. In this paper, a distinction is made between "strategic" TSM planning (which focuses on systemic, intermodal effects and the achievement of regional goals and objectives) and "tactical" TSM planning (which is more concerned with localized, intramodal transportation problems). By far the most common example of TSM planning is found in the tactical category, although one should be quick to point out that there are not one but many TSM processes throughout the United States. Further, TSM has become a conceptual touchstone for many different processes, ranging from air quality planning to being a source of leverage in furthering urban development objectives.

In developing a monitoring program, the type of decisions and planning associated with the TSM actions, i.e., whether they are strategic or tactical in nature, will greatly influence the structure of the program and the type of information needed. What would be the structure of a monitoring program in the case of strategic TSM planning? In the case of tactical TSM planning? And what elements of each can be combined into a monitoring program that will rely on the strengths of both approaches? Two types of monitoring programs are described below—one that examines the structure of such a program in a strategic TSM planning process and one that looks at the role of monitoring in a TSM process based solely on tactical planning. In each case, the types of information needed and the responsibilities of the respective agencies are specifically addressed.

Monitoring in a Strategic TSM Planning Process

In a strategic TSM planning process, the major purpose of monitoring is to provide the information needed to relate the effectiveness of the TSM program to regional goals and objectives. Implicit in this approach is the development of measures of effectiveness (MOEs) that can be used to evaluate the individual TSM actions in light of their impacts on regional goals. Because the scope of such a monitoring program is at the regional level and cuts across modal operations, the MPO must take the lead role in developing the format for data collection and establishing the decision-making process in which the information is to be used. The operating agencies such as the transit authority or highway department will collect information on TSM projects for which they are responsible. The information will then be forwarded to the MPO, where it will be used to determine the particular effectiveness of any individual strategy in regard to regional goals and objectives and also to evaluate the overall effectiveness of the TSM program.

The key to this monitoring program is that MOEs can be developed that are (a) measurable and (b) easily related to the goals and objectives of the transportation program. These measures are the basis for predicting effectiveness before implementation and by surveillance afterwards. MOEs thus provide "the basis for a TSM information system which can be the foundation on which a continually improving program of TSM action implementation can be built" (15). Two measures that have been used in the past to determine TSM program effectiveness include regional vehicle occupancy and person travel (5,6). To accurately assess changing commuting patterns, however, a continuing program to monitor
carefully selected sites at regular intervals is necessary. Variations in the data collected, such as those accounted for by season, must be adjusted for. This information, along with that from the TSM strategy-specific monitoring, will then be considered in decisions to change specific components of the TSM program.

A strategic TSM planning process thus implies that the MPO will play a significant role in directing the monitoring program for the region, not only in developing the format for data collection but also in assigning responsibilities for monitoring activities to the various agencies. Further, the type of information gathered will not only relate to specific TSM strategies but also attempt to measure on a regionwide basis the effectiveness of a TSM program. This means that one of the first tasks in developing a strategic monitoring system is to identify those MOEs that will be used as criteria for determining TSM program effectiveness. Monitoring can then be conducted on a continuing basis to collect the information necessary to determine attainment of goals and objectives. One modification of this approach is to design the monitoring program on a corridor-by-corridor basis, which will allow TSM planners to structure the data-collection procedures to address the specific travel characteristics of each corridor. This information can then be aggregated in such a way as to obtain some estimate of the regional effectiveness of the TSM program.

An example of the relationship between TSM goals and objectives and MOEs is shown in Table 1, and similar matrices could be developed for the entire set of TSM tactics that are appropriate for a metropolitan area. The role of monitoring in this strategic framework is to gather the information needed to relate the MOEs to the attainment of specific TSM objectives. Information such as average delay per vehicle, number of accidents per million vehicles, and volume-to-capacity ratios are best obtained from the agency responsible for implementing the specific tactic. The role of the MPO is to take this information and relate it to strategic TSM objectives to evaluate the overall effectiveness of the TSM program.

Table 1. Measures of effectiveness for various traffic operations tactics.

<table>
<thead>
<tr>
<th>TSM Objective</th>
<th>MOE</th>
<th>1: Intersection Widening</th>
<th>2: One-Way Streets</th>
<th>3: Turning Movement Lane-Use Restrictions</th>
<th>4: Turning Movement Lane-Use Restrictions</th>
<th>5: New Freeway Lane Using Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>Point-to-point travel time</td>
<td>Avg travel time between selected locations within project impact area during peak and off-peak periods</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Vehicle delay</td>
<td>Avg delay for all vehicles during peak and off-peak periods, measured for each approach</td>
<td>Avg delay for all vehicles during peak and off-peak periods measured by direction over project impact area (also, at intersections, see tactic 1)</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Avg delay for all vehicles during peak and off-peak periods, measured by direction over project impact area</td>
<td></td>
</tr>
<tr>
<td>Vehicle stops</td>
<td>No. of stops for all vehicles, measured for each approach</td>
<td>Avg no. of stops by direction over project impact area (also, at intersections, see tactic 1)</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Vehicle hours of travel</td>
<td>Vehicle hours of travel within project impact area during peak and off-peak periods</td>
<td>Vehicle hours of travel within project impact area during peak and off-peak periods</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Annual no. of accidents by type and severity within project limits</td>
<td>Annual no. of accidents by type, severity, and location within project limits</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Accident rate</td>
<td>No. of accidents per million entering vehicles</td>
<td>No. of accidents per unit no. of vehicle kilometers</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Freeway incidents</td>
<td>Comfort and convenience</td>
<td>No. and percentage of parking spaces occupied by location within project impact area</td>
<td>No. and percentage of parking spaces occupied by location within project impact area</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Vehicle delay</td>
<td>Avg delay for all vehicles during peak and off-peak periods, measured for each approach</td>
<td>Avg delay for all vehicles during peak and off-peak periods, measured by direction over project impact data (also, at intersections, see tactic 1)</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>Variance of avg point-to-point travel time</td>
<td>Variance of avg point-to-point travel time as described above</td>
<td>Variance of avg point-to-point travel time as described above</td>
<td>Same as tactic 2</td>
<td>Same as tactic 2</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>Level of service</td>
<td>Level of service corresponding to the volumeto-capacity ratio defined below</td>
<td>Level of service corresponding to the volumeto-capacity ratio defined below</td>
<td>Same as tactic 1</td>
<td>Same as tactic 1</td>
<td></td>
</tr>
<tr>
<td>Volume-to-capacity ratio</td>
<td>Ratio of peak-hour traffic volume to capacity at selected locations within project limits</td>
<td>Ratio of peak-hour traffic volume to capacity at selected locations within project limits</td>
<td>Ratio of peak-hour traffic volume to capacity at selected locations within project limits</td>
<td>Same as tactic 1</td>
<td>Same as tactic 1</td>
<td>Same as tactic 1</td>
</tr>
</tbody>
</table>
Monitoring in a Tactical TSM Planning Process

In a tactical TSM planning process, the major purpose of monitoring is to gather data on existing system or facility performance and relate them to specific actions to be taken by individual agencies. In this approach, no attempt is made to gauge the effectiveness of a regional TSM program because, by definition, the TSM program consists of the separate planning activities of individual agencies. The MPO will attempt to coordinate these planning activities but, with specific regard to monitoring, has a very small role to play. At best, it can play an active role in the planning, monitoring, and evaluation of innovative or regionally oriented projects, i.e., projects that do not currently fall under the jurisdiction of any particular agency.

One of the more advanced monitoring approaches in this category (and indeed one that is closely related to transportation system monitoring in a strategic process) is the concept of a system performance indicator. There has been considerable attention given in recent years to the development of performance indicators, especially in the transit industry (17, 18). These indicators, which give the transit operator some information about the level of effectiveness and efficiency at which the system is operating, include (19):

1. Total ridership,
2. Ridership per route kilometer of service,
3. Ridership by category of rider,
4. Ridership per vehicle kilometer,
5. Ridership per vehicle hour,
6. Ridership per capita,
7. Ridership per employee, and
8. Ridership per dollar of cost.

Some efforts are currently under way to automatically collect bus passenger boarding and alighting and travel time information by route segment for each trip. The transit information system concept, for example, which is being tested in Cincinnati, uses wayside bus locators, on-board passenger-counting equipment, and real-time transmission of data via radio to a central computer, where the information is edited and put in report form for use in service planning and scheduling (20).

Efficiency indicators relate units of cost or work to units of service or other types of output, e.g., mechanics per vehicle, vehicle kilometers per operator, annual kilometers of service per vehicle, costs per hour, costs per rider, or costs per passenger kilometer.

In most cases, what distinguishes these indicators from those used for strategic planning is that they are not used to determine system impact on regional objectives relating to such factors as air quality, congestion, mobility for the elderly and the handicapped, energy, center city development, and quality of life. The monitoring program is aimed solely at obtaining information that can be used by transit managers and highway officials to determine the performance characteristics of the particular transportation system for which they are responsible.

In summary, monitoring in a tactical TSM planning process involves defining a limited number of key data items that can be measured efficiently and used as basic input for routine planning decisions, the identification of appropriate data-collection techniques, and the development of a sampling plan for their application. Design of the monitoring phase requires answering nine questions:

1. What data are needed for effective planning?
2. Which items can be measured directly at reasonable cost and which are better measured through surrogate items?
3. What level of accuracy is needed in the measurement of each data item?
4. What is the variability in each data item?
5. What are the possible data-collection techniques?
6. What data can each technique provide?
7. What combinations of techniques can provide all the required data?
8. What sample sizes are required for each data item, given its underlying variability and the desired accuracy?
9. What is the minimum cost combination of techniques?

For certain planning decisions, the data collected in the monitoring phase will not be sufficient; in this case, it will be necessary to gather additional data.

DEVELOPMENT OF A MONITORING PROGRAM FOR TSM PLANNING

Clearly, a TSM monitoring program should reflect both the institutional responsibilities for planning and implementation and the technical capabilities to successfully carry out the monitoring process. The minimum level of effort for an effective TSM monitoring program should attempt to satisfy the following objectives:

1. To provide information on system problems that can be treated by TSM measures;
2. To provide advance knowledge of the relative merits of alternative TSM actions;
3. To alert agencies to the fact that their participation is on display and thereby generate pressure toward the advance of their respective proposals; and
4. Perhaps most important, to provide an output on which to base the overall TSM strategy.

There are several ways by which monitoring activities can assist in strategy development. For example, monitoring can distinguish the impacts of particular actions on various objectives—reduction of VT, increase of passenger throughput, increase of local amenity, and so on—to aid in balancing the trade-offs among objectives. Similarly, monitoring can lead to increased understanding of the cumulative consequences of TSM actions. Indications are mounting that, although overall objectives can be listed and the projects that tend to accomplish them can be identified, the real question is the extent to which such projects really serve the objective after, say, 10 years of implementation. Estimates of future cumulative impacts give the impression that the payoff will be disappointingly low. This is not surprising. When objectives and the means of achieving them are not analyzed in relationship to one another, it is understandable that the more-convenient, nominally relevant actions will constitute the majority of those proposed.

By far the largest number of TSM actions planned and implemented in any area are those that proceed naturally through an operating agency's planning, design, and implementation procedures. The decisions regarding these projects are made internal to the organization, and monitoring project performance is necessary only to the extent that more information is needed to make these routine decisions. Aggregate information, such as total ridership, should be given to the MPO planners so that a regional data file can be kept on all system components. There are other types of TSM actions, however, that require a planning and decision-making process that cuts across established agency responsibilities. Such actions are usually regional in scope, require the par-
ticipation of several jurisdictions, are not the sole responsibility of any one agency, and are typically considered an innovative application of a new or modified service concept.

Thus, there are several types of actions that must be carefully monitored. These are actions that show a variety of characteristics: (a) the prospect of substantial positive effects (compared with the costs involved) is uncertain or in need of demonstration to some participants or interested observers; (b) the avoidance of excess negative impacts is not ensured or must be shown; and (c) the system of implementation is experimental and may need to be changed. Typical TSM actions falling into these categories include

1. Service improvements—such as subscription buses or vans, shared-taxi services, park-and-ride lots, and coordination at transfer points;
2. Preferential treatments—such as with-the-flow or off-the-flow bus lanes, ramp bypasses, and signal preemption;
3. Pricing and fare-collection policies—such as bridge tolls, area licensing, parking strategies, special fares, and no-fare services;
4. Institutional changes—such as staggered work hours; and
5. Amenity improvements—such as automobile-restricted zones, pedestrian malls, and transit malls.

Most of these innovations are normally monitored under agency operating procedures by that organization responsible for implementing the action. Thus, many of these actions may not be part of a TSM monitoring process focused on a regional program. Also, the level of controversy and the degree of impact of each type of action are sure to differ among metropolitan areas, which makes it difficult to determine which projects are prime candidates for monitoring. In Boston, for example, an automobile-restricted zone and a park-and-ride project have become prime candidates for the TSM monitoring process. At one time in Atlanta, a ramp-metering project was the focus of regional attention. One can imagine, given recent experience, that preferential lanes on freeways could be subject to detailed monitoring in southern California.

Once a TSM project of one of these types has been implemented, several types of decisions that require information on project performance will eventually be necessary. First of all, one must ask, What impact is this project having on the behavior of travelers or on the ability of the transportation system to handle a changed demand? Second, What aspects of the project can be changed to result in a more desirable impact? And third, Is it feasible to implement this type of project in other parts of the metropolitan area? The type of project monitoring needed to obtain the information for answering these questions thus has two components: (a) a periodic collection of data for use in modifying the project concept during the initial period following implementation and (b) a collection of information needed as input to a full-scale evaluation. This latter task at times involves the existence and magnitude of changes in such attributes as congestion, vehicle occupancy, transit ridership, and air quality; to measure the extent of the changes attributable to the project; and to identify those characteristics or factors that reinforce or mitigate the changes. Thus, some of the information gathered for these projects will be project specific and chosen by the operating agency, while other information (especially on effects on regional objectives and feasibility analysis) will be standardized by the MPO.

Because these types of projects require interagency coordination and also necessitate an attempt to relate project performance to regional goals and objectives, the MPO should play an active role in evaluating them. The MPO, in cooperation with the relevant operating agencies, must agree during the formulation of the evaluation-study design who will be responsible for collecting the necessary information and what will be done with it once collected. In the case of regionally relevant TSM projects, the MPO should be directly responsible for their evaluation, although it can rely mainly on the operating agencies to collect the needed data.

Thus far, the monitoring program proposed in this paper is probably very similar to that which currently exists in most metropolitan areas. As discussed above, however, one of the most important outputs of monitoring could be in distinguishing the impacts of particular TSM actions on various TSM objectives. This could be done by a carefully designed monitoring program. For example, the idea of establishing monitoring posts on the major routes into an urban area and then attempting to relate the effectiveness of a TSM program would be, from an experimental design point of view, most ineffective. So many factors external to the transportation system itself influence travel behavior that it would be almost impossible to determine the cause-and-effect relationship between a TSM program and transportation system performance. Also, to make any conclusion meaningful, the monitoring techniques and statistical measures used to measure the impact would have to be extremely precise and the mere cost of such a program would most likely be prohibitive. Finally, in most cities, there is no such thing as a TSM program. Clearly, system performance must be monitored and VT, transit ridership, vehicle emissions, vehicle occupancy, and other measures should be closely watched to identify trends, but this type of monitoring should be part of the overall transportation planning process, rather than only for a TSM program.

One way to address these issues is to adjust the scale of monitoring to the level of analysis that occurs in TSM planning. Whereas it is very difficult to determine on a regional basis what impact the TSM program is having on system performance, focusing on subareas or corridors could allow a planner to draw conclusions about the effects on travel behavior and the environment of specific TSM strategies in that corridor. By focusing on a corridor, one can largely avoid the problem of events in other areas of the region affecting the variables that are being measured. Also, the effects of TSM strategies are much more easily discerned when the boundaries of the study area are reduced to include only the immediate impact area. Finally, a corridor-based monitoring program can tailor the monitoring procedures and data gathered to the specific characteristics of the corridor. In corridors where transit ridership is high, it makes sense to include in the program some measures of transit system performance, whereas in corridors that have low levels of transit service, it makes greater sense to emphasize other measures.

The question of corridor-based monitoring highlights an important consideration in developing a TSM monitoring program—How should monitoring procedures be tailored to the size of an urban area? Clearly, the approach suggested above for a minimum TSM monitoring program applies for any size city, i.e., the operating agencies monitor the projects that are internal to their own organization and report system performance measures to the MPO, while the MPO takes the lead in evaluating systemwide, innovative, intermodal TSM projects. In small and medium-sized cities, however, focusing on corridors may not make as much sense as looking at the
regional level. Furthermore, the impact of TSM projects in small cities is probably much greater than the impact of similar projects in larger cities.

The key concept in developing a monitoring program for any size city is that the information to be gathered must be related to the directions that have been set for transportation planning. In large cities, where the problems are complex and severe, an extensive monitoring system will be necessary. Thus, the extent to which goals and objectives in small cities are different from those in large cities is the extent to which the emphasis in their monitoring programs is different.

Because the information that is gathered from data collection activities is used in making decisions about project and program implementation, it should be easily comprehended and relevant to the decision-making situation. It is, however, infeasible to suggest in this paper a format that should be used for reporting the results of TSM monitoring, although a format should indeed exist. At the minimum, each project evaluation or corridor monitoring report should provide information on specific TSM MOEs, if for no other reason than to provide a basis for comparison between strategies. These TSM measures should be related to the established regional goals in that they will give some indication of which goals and objectives are being addressed.

CONCLUSION

Monitoring the performance of the transportation system and the impacts of individual actions is the key to an effective TSM planning process. This has been recognized by most TSM planners, and a wide range of monitoring processes have been established. Any monitoring program should be designed to provide the information needed to make decisions about specific projects and also should rely, to the extent possible, on the existing capabilities of agencies within the metropolitan area.

A large number of the TSM projects planned, designed, and implemented each year need not be the concern of a TSM monitoring program or of an MPO involvement. Aggregate information on system performance, however, which includes the summed impacts of all the individual projects, should be forwarded to the MPO. However, projects that are regionally significant should be monitored closely by both the MPO and the operating agencies, so that modifications can be made during initial implementation to improve service performance and evaluations can be conducted to determine the feasibility of this type of project in the metropolitan area.

In summary, then, the TSM monitoring program for a metropolitan area should have the following characteristics:

1. Those TSM actions that have been the responsibility of operating agencies in the past and have no significant impact on the regional transportation system will be monitored only to the extent that the operating agencies need additional information to make decisions about future project implementation.

2. Regional projects and those that do not fall naturally under the purview of one agency will be monitored in a cooperative manner by the MPO and the relevant operating agencies. The evaluation of these projects will include MOEs that relate closely to the stated TSM goals and objectives and will thus serve as a basis of comparison between TSM projects.

3. System performance indicators, on a regionwide basis, will be used to monitor the performance of the transportation network and identify trends in travel behavior. This monitoring activity will be part of the ongoing transportation planning process for the metropolitan area. Efforts to relate TSM program effectiveness with system performance must be carefully designed so that causal relationships can be clearly established.

4. When appropriate, corridor-based monitoring systems will be used in those corridors where TSM actions are being implemented. The results of this monitoring will be used by MPO staff to determine which TSM goals and objectives are being addressed. This implies that a standard set of measures will be used in all TSM evaluations in each metropolitan area.

This proposed monitoring program very much depends on the willingness of MPO and operating agency staffs to cooperate in gathering and using the needed information. This program is designed to reflect the existing institutional relationships in most metropolitan areas and is thus one attempt to determine what is feasible given these constraints. By no means is it the only alternative. There are probably as many different approaches to monitoring as there are cities in the United States. One thing is certain, however—the monitoring of system performance and of individual actions forms a strong foundation for transportation, and specifically TSM, planning.

REFERENCES


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