Transportation Management System Performance Monitoring, Evaluation, and Reporting

A Primer for Practitioners

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7. Authors Byungkyu (Brian) Park		**8. Performing Organization Report No.**
9. Performing Organization Name and Address University of Virginia Department of Civil Engineering PO Box 400742 Charlottesville, VA 22904-4742		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-01-C-00180
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16. Abstract

This primer provides an overview of TMS performance measurement and introduces the reader to the idea of establishing a performance measurement program; developing individual and detailed performance measures for various functions and sub-functions of a TMS; data collection, screening, archiving and processing efforts; and performance monitoring, evaluation and reporting. This primer principally addresses the equipment, systems, and programs involved in a TMS that can be used to obtain the most efficient and desirable outputs and outcomes.

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Introduction to Transportation Management Systems

Transportation engineering has evolved significantly in the recent past. Along with the traditional solution of capacity enhancements and construction of new roadway facilities, improving the operational efficiency of the existing facilities is increasingly being pursued throughout the nation and the world. The technology components used for such operational improvements are usually referred to as Intelligent Transportation Systems (ITS). Various ITS elements are often grouped together to provide viable solutions to local transportation problems and help build the visions of the communities. A Transportation Management System (TMS) provides a broader context, and may be loosely defined as the deployed form of ITS, which, along with the human resource factor, contributes to transportation management. In particular, TMS includes computer hardware, software, communications, and surveillance technologies that service freeway and arterial systems. A traffic management center (TMC) is the physical facility that houses central equipment, software and personnel to monitor, control, and operate one or more TMSs.

TMSs are categorized based on the type of functions they perform. The TMSs controlled by transportation agencies at all levels (states, metropolitan regions, counties, and cities) frequently focus on managing three particular systems – the freeways, the arterials, and transit. Other specific types of TMSs include emergency management, toll ways, etc. Each TMS is further composed of several different functions. For example, a freeway TMS could include functions such as incident management, special event management, ramp metering, work zone management, etc. Depending on the size of the region under the scope of a TMS, the number/type of activities and personnel involved in the traffic management functions could be quite complex. There are mainly three stakeholders extremely and directly interested in the degree of performance of a TMS: the TMS manager, the traveling public, and the elected officials.

Performance Monitoring, Evaluation, and Reporting

Three important outputs for the successful implementation of a performance measurement program are performance monitoring, evaluation, and reporting. Performance monitoring is defined as a regular review of metrics and budgets against the projections plan. Another way to define performance monitoring is as an ongoing internal process of examining the actual system condition through observed data. Performance monitoring often involves the following three functions:

- Examines the incoming streams of data.
- Compares the incoming data to the expected data and the existing goals and policies.
- Flags any outliers for further study (detailed evaluation).

An operator is likely to monitor traffic on some sections or corridors on a minute-by-minute basis. A supervisor is likely to monitor traffic at the network or regional level regularly, with emphasis on specific sections on an ad hoc basis. A TMC manager is likely to review the system- and policy-level attributes of the region on daily basis, emphasising a specific day when necessary.

The next step in the performance measurement program is evaluation. Evaluation is the process in which the collected data are analyzed and the results are compared to benchmark performance measures. The purpose of performance evaluation is to determine how well goals are met so that appropriate changes can be made to the TMC operations (such as policy, planning, maintenance, etc.). The evaluation process also is helpful in selecting alternative procedures and refining management techniques.

The performance measures being monitored can raise three significant concerns to an agency:

- Were the correct investments made?
- Are demands of the public and state legislature being met?
- Are agency goals and objectives being met?

This step in the process also identifies areas for system improvement and provides information that later will be reported to decision makers and the public. An example is the Highway Performance Monitoring System sponsored by Caltrans. The data collected from this system are used to determine:

- Allocation of funds to the policies.
- Travel trends and future transportation forecasts.
- Environmental Protection Agency (EPA) air quality conformity tracking.

Once the best procedures are determined from the evaluation process, the results need to be reported. Reporting provides visual information about the data. The frequency of reporting (i.e., weekly, quarterly, or annually) varies from agency to agency. The report gives feedback on the planning and decision-making process, on trends in system performance, accomplishments, and areas of needed improvement. Using this information, the analyst can recommend changes to policy goals and objectives, performance targets, and performance measures.

Performance Measurement Program

Purpose & Benefits

All organizations, whether public or private, are interested in developing and implementing effective performance measurement programs, since it is only through such programs that organizations can maintain efficiency. In a broad context, performance measurement is the use of quantifiable indicators of program effectiveness and efficiency to determine progress toward specific, predefined organizational goals and objectives. Performance measures related to transportation systems can be grouped into three categories: input, output, and outcome measures. Input measures address the supply of resources available to implement a program; output measures quantitatively address the delivery of transportation programs, projects and services; and outcome measures address the degree to which the transportation system meets policy goals and objectives. A specific example is shown in Table 1.

Table 1: Examples of Types of Measures (FHWA 2004)

Measures	Traditional Capacity	Maintenance and Operations Oriented
Input	Capital projects budget	No. of incident response patrols
Output	Miles of roadway built	Response time to incidents
Outcome	Reduced miles of congestion	Change in incident-related delay

Performance management encompasses setting the agency/program goals appropriately and revising them as needed. Figure 1 illustrates some important aspects of performance measurement and their relation to performance management.

Figure 1: Linking Performance Management to Performance Measurement (ICMA 2005)

A TMS needs a performance measurement program for many reasons. Federal and state statutes require the implementation of a performance measurement program. Stakeholders such as legislative decision makers and taxpayers are rightly inquisitive about how their tax dollars are spent in the transportation domain. A performance measurement program also is needed to provide performance trends over time and, ultimately, strategic feedback for decision makers. Box 1 highlights the potential benefits from a performance measurement program.

Motivations of a Performance Measurement Program

Accountability: Performance measurement provides an increased accountability of public expenditures for internal and external purposes. Performance measures allow the determination of efficient or inefficient resource allocation dependent upon pre-identified priority needs via performance reporting. They also allow for the quantification of program benefits and can ultimately increase agency visibility and incoming funding.

Efficiency: Performance measures focus actions and resources on organizational outputs and the process of delivery. Performance measurement is an internal management process.

Effectiveness: Performance measurement encompasses planning and goals achievement. It also serves to link outcomes of policy decisions and immediate actions of transportation agencies, as well as strategic planning to resource allocation.

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Motivations of a Performance Measurement Program (continued)

Communications: TMS performance results must be shared with customers in order to obtain their support for current and future investments. A performance measurement program provides better information to customers and stakeholders on progress made toward desired goals and objectives, as well as deterioration of performance if applicable.

Clarity: Performance measurement serves to clarify the purpose of an agency's actions and expenditures.

Improvement: A performance measurement program allows for periodic refinement of programs. Taxpayer money must be spent as efficiently as possible in efforts to improve how agencies provide transportation (Transportation Research Board 2003).

Box 1: Potential Benefits of a Performance Measurement Program (NCHRP Synthesis 311)

The performance measurement process starts by defining the services that the organization promises to provide, including the quality or level of service (e.g., timeliness, reliability, etc.) that is to be delivered. Performance measures are then used to prioritize projects, provide feedback on the effectiveness of long-term strategies, refine goals and objectives, and improve processes for the delivery of transportation services. They reflect the concerns of the transportation service user and system operator and provide useful information to managers and decision makers on how well the system is performing.

Steps to Establish a Performance Measurement Program

Several key steps must be completed to completely establish a performance measurement program. These include:

- Identify the vision, goals, and objectives of the agency. Involve stakeholders in defining these three items.
- Identify intended uses and audiences.
- Develop TMS performance measures and relate to respective programs.
- Identify performance benchmarks.
- Collect complete, accurate and consistent data and monitor this data in a way that supports decision making.
- Analyze and evaluate data.
- Report data to stakeholders in a useful manner.
- Identify action areas and communicate them to stakeholders.

Performance Measures

The range of needs and uses of potential performance measures must be well understood before an agency can determine which performance measures to implement. A good, worthwhile measure is defined clearly

and is directly related to predefined goals and objectives. It is understandable, logical, and allows for repeatability. It also allows for data collection and shows trends. Further, these measures should be reviewed according to the criteria in Box 2.

Criteria for Defining Performance Measures

Purpose: Is the measure worth collecting and does it aid in decision making?

Validity: Does the measure actually measure its intended purpose?

Precision: Does the measure return consistent values with each measurement?

Accuracy: Does the measure match the true value of the attribute?

Cost-effectiveness: Is the required evaluation and reporting of the measure within budget?

Box 2: Criteria for Defining Performance Measures (Hack, 2005)

The following illustrate some examples of common TMS performance measures:

Incident Detection Rate and False Alarm Rate (FAR)

These metrics are used to measure the performance of incident detection algorithms. The detection rate can be taken as the percentage of incidents detected by the software versus the number of incidents that occur. The FAR can be taken as the percentage of false alarms versus the number of tests run by the software. Factors that may affect the performance of an incident detection algorithm include: the operating conditions of the roadway (at or below capacity), the duration and severity of the incident, the geometric characteristics of the roadway (grade, change in the number of lanes, presence of ramps), weather (including the condition of the road surface as wet or dry), detector spacing, the location of the incident with respect to a detector, and the diversity of the traveling vehicles.

Delay

This traffic performance metric measures added travel time caused by congestion. It can be calculated as:

$$\begin{aligned} &\textit{Total Segment Delay (veh - min)} = [\textit{Actual Acceptable Travel Time (min)} - \\ &\textit{Actual Travel Time (min)}] \times \textit{Volume (veh)}, \end{aligned}$$

$$\textit{Total Delay (veh - min)} = \sum_{i=1}^{n} \textit{Segment Delay}_i$$

Equation 1

Acceptable travel time for expected conditions is generally based on the posted speed limit but may "be calculated using a congestion threshold speed established from local performance goals for mobility." "Acceptable travel conditions" are usually free-flow (Federal Highway Administration 2002).

Another method is to measure the divergence of the actual travel time from the expected travel time. Equation 2 can be used to calculate delay over a set of links assuming free-flow conditions.

$$D = \sum_{i=1}^{n} L_i \times F_i(t) \times \left[\frac{1}{V_i} - \frac{1}{f_i} \right]$$

Equation 2

Where,

L_i = The length of the *i*th segment holding the *i*th TMS, which can be derived from adjacent TMS locations marked by milepost value.

$F_i(t)$ = The total volume at the ith TMS site for the specified period t.

f_i = The free-flow speed at the ith segment.

Stakeholders

The Victoria Transport Policy Institute defines stakeholders as "individuals or groups that are affected by a decision and have an interest in its outcome." With respect to a TMS, stakeholders are interest groups who benefit from, or are otherwise impacted by, a TMS and its operations. Stakeholders include the following:

- Agency management and staff.
- Transportation professionals:
  - Transportation providers.
  - Transportation system users.
- Citizens.
- Elected officials.
- Policy makers:
  - FHWA.
  - State DOTs.
  - Metropolitan Planning Organization (MPO).
  - Municipalities.
  - Emergency Responders and Management.

Stakeholders are interested in performance measures and the associated monitoring, evaluation and reporting processes for the following reasons:

- Improving transportation to serve people and commerce.
- Improving management access to relevant performance data.
- Improving agency efficiency and effectiveness in terms.
- Returning on investment in transportation.
- Efficient allocation of investment in transportation.
- Accountability of the agency.

When establishing performance measures, it is imperative to involve stakeholders such as those involved in freeway and signal systems, planning operations, emergency management, and departments of transportation. The stakeholders should be involved in each phase of a performance measurement program, including the processes of defining performance measures and how they are to be used. Stakeholder support is critical for initial acceptance and continued success of the performance measures. Without stakeholders considering the determined measures appropriate, it is "impossible to use the results of the analysis process to report performance and negotiate the changes needed to improve it. Those who are expected to use the process to shape and make decisions should be allowed to influence the design of the program from the beginning." Those persons accountable for results but who are not necessarily decision makers, such as data collectors, should be involved. Their involvement is necessary to gain their support so that they do not circumvent the process or its intended outcome.

A very important group of stakeholders are the citizens, or transportation system users. Accordingly, agencies need to focus on measuring citizen satisfaction and communicating these results to the group. For example, customer satisfaction may be measured from the results of focus groups and surveys. The city of Phoenix, Arizona, has shown great success in involving stakeholders, decision makers and citizens in its performance measurement program. Box 3 highlights this best practice. Its tactics and strategies can easily be transferred to a TMS performance measurement program.

Phoenix, AZ

As a pioneer in the public sector in the area of performance measures, Phoenix, AZ, is no stranger to the concept of a performance measurement program. One of the city's visions states: "We focus on results. The belief and commitment in results information has taken time to grow and mature. The city of Phoenix credits its success in measurements to citizen input." In the 1990s, the City Auditor Department began to develop indicators to reflect inputs, outputs, efficiency, and outcomes. Though these indicators were helpful, some management questioned the purpose of performance measurements. In 1991 "citizens were able to attend one of several focus groups held around the city to give their input as to what was important to them about Phoenix." These focus groups helped develop results indicators and their purpose, clarifying "discrepancies between what managers thought citizens wanted in terms of service delivery and citizens' actual expectations." Over 450 citizens participated in these brainstorming sessions.

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Phoenix, AZ (continued)

Many city departments use a more direct approach for citizen feedback. "For example, the Police Department will gather a group of citizens and tell them, 'You're our customer, we're the service provider, we spend lots of money. Where should we be focusing our effort? What's important to you?' They keep it very simple. From these conversations, the department can determine what they should be focusing on and, thus, what they should be measuring."

To reach out to citizens, other means of communicating performance measurements were developed in reporting. "Performance measurement did not become a way of life at the city of Phoenix until customer feedback began to be compiled on what was important to measure. Department management cares about satisfying the customers, and if performance measures can be used as a tool to accomplish this, managers will take the time to use them. Managers stressed that it is important for them to know that they are not just measuring for the sake of measuring; or tracking a certain measure just because the data are easy to get."

"Employees are seen as an important group of people to include in the development process. This includes front-line staff, supervisors, and all the way up the chain. It was often mentioned that they strive to get employee buy-in before implementing measures. Many times employees were included in focus groups when the City Auditor Department was helping departments develop performance measures. One of the reasons cited for getting the employees involved is to gain their buy-in to the whole process. Employees are the ones who will end up gathering, calculating, and maintaining the data needed for measures. Because of this, interviewees felt that it is vital that employees see the importance of the process." (Artrip 2004)

Box 3: Phoenix, AZ, Best Practice of Stakeholder, Decision Maker, and Public Involvement

TMS Performance Monitoring, Evaluation, & Reporting

Performance monitoring is primarily an operational task that allows real-time (or immediate) decisions to be made based on the up-to-date information produced by the system. There are multiple purposes for monitoring this information, such as:

- Identifying transportation systems or corridors with poor performance.
- Calculating the degree to which transportation facilities are meeting goals and objectives established for those facilities.
- Determining specific areas of management programs or systems that require improvements.

An example of traffic performance monitoring comes from the Archived Data Management System (ADMS) web site, which stores and allows access to Virginia traffic data. Figure 2 shows graphs from the ADMS Daily Report, which will be implemented in an upcoming build of ADMS. This report provides a way for State transportation officials to monitor the TMS status. The left graph, for instance, gives the speed index value, the average percentage of the speed limit traveled on area freeways for the previous week. The middle graph provides an updated incident count, and the right graph shows the percentage of stations available to collect data. Using these three performance measures, TMC officials can monitor system mobility, safety, and the effectiveness of field equipment.

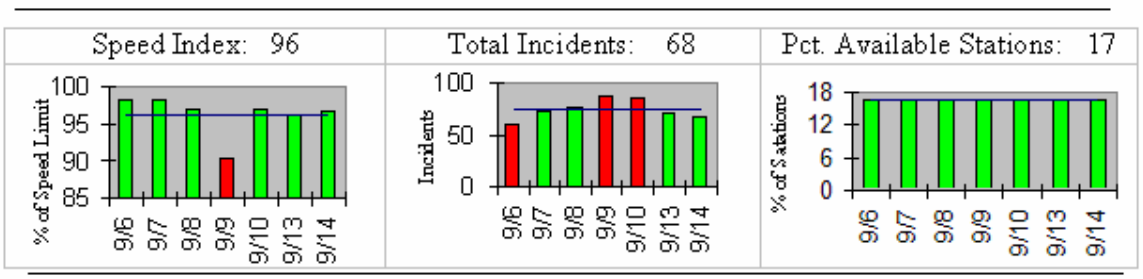

Figure 2: ADMS Daily Report Graph Examples

Currently, TMC operators as well as the public can monitor the performance of corridors and freeways through images obtained via traffic cameras, where they are available over the Internet, cable TV or other medium. For example, Figure 3 shows a screen shot of the New York City TMC's Advanced Traveler Information System. The web site (http://www.nytmc.org) allows the user to view streaming video or a still image from a number of New York area intersections, providing the public with valuable, real-time traffic conditions at points around New York City.

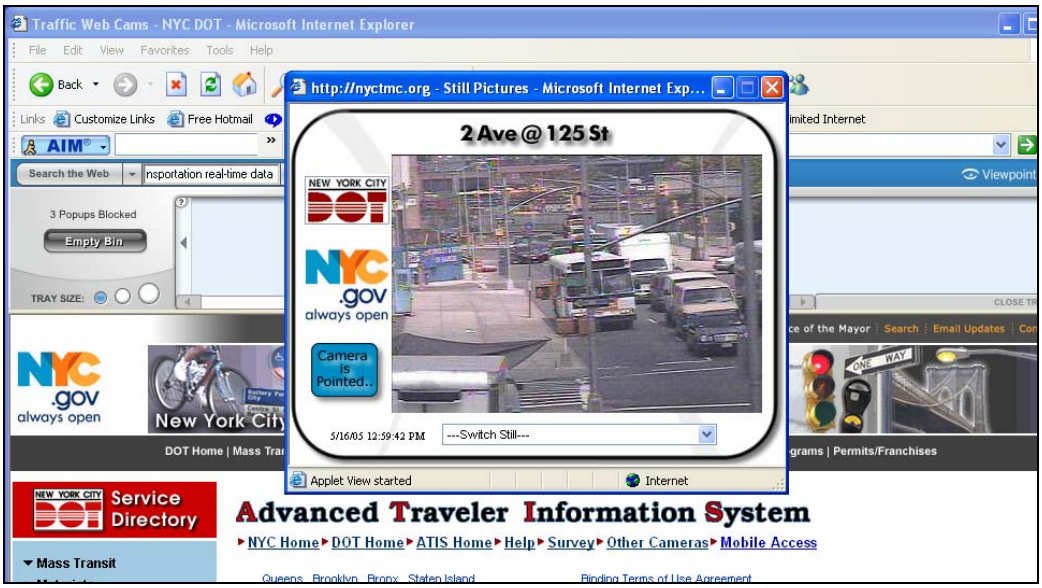

Figure 3: Real-time Image of an Intersection from the ATIS of the NYC TMC

The San Diego TMC displays another type of real-time information to both the public and TMC operators. Figure 4 exhibits the TMC's real-time map, which reports the current speed on any given section of highway or freeway.

Figure 4: San Diego TMC Real-time Map

In this example, the menu located on the left allows the user to select a specific freeway and direction. Based on this selection, the current traveling speeds at various points on the corridor are displayed on the right side of the screen. A large, speed-based, color-coded map of the area also is displayed in the center of the screen, illustrating where construction will soon occur. In addition, the color-coded map can help operators identify segments where sensors are not working properly or extreme congestion is present.

For TMS or TMC managers, performance monitoring can be accomplished via a regularly released report. Such reports update transportation officials on the condition of specific TMS components (e.g., traffic sensors, signals, etc.) and overall system performance. For instance, officials in Northern Virginia are currently working to produce a daily report on the condition of the high-occupancy vehicle (HOV) facilities in the area, along I-95 and I-395. The report displays the previous weekday's speed and volume data for both morning and afternoon peak periods in the HOV lanes compared to the average speed and volume from the previous month. Figure 5 shows a typical data table from this HOV daily report.

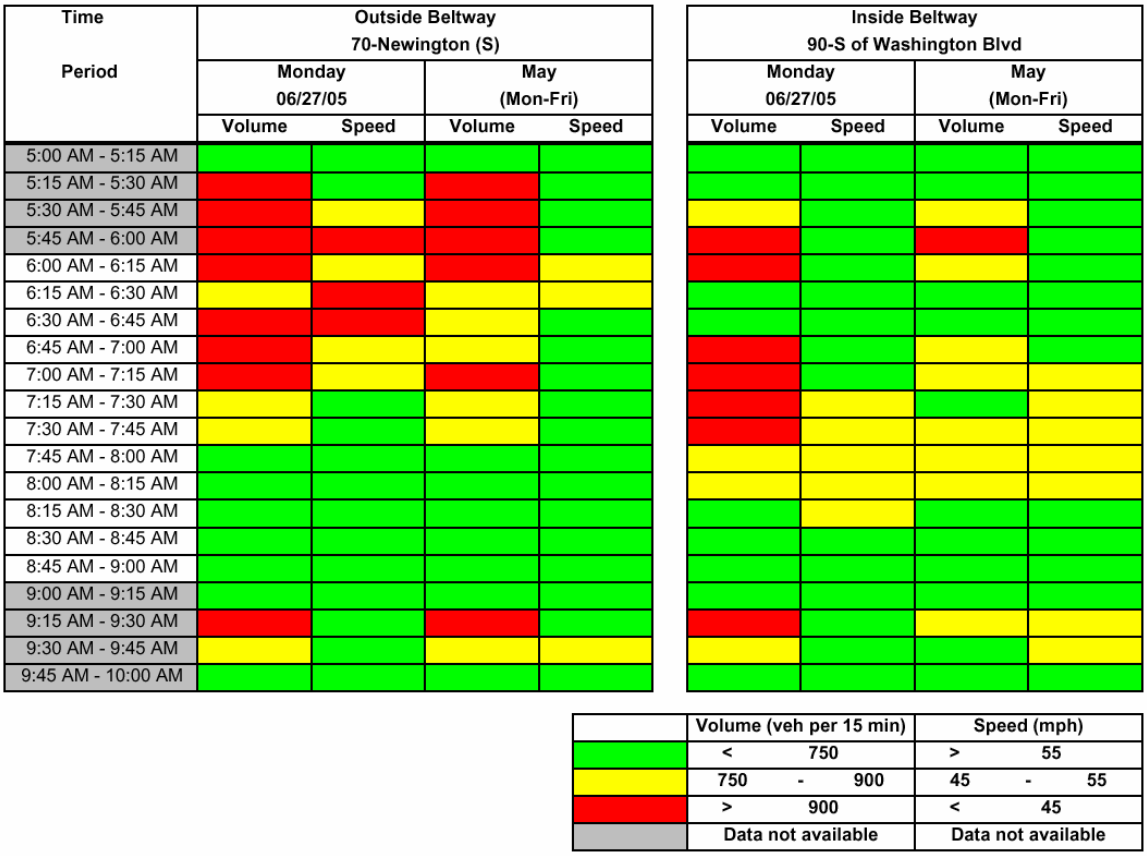

Figure 5: Analysis for HOV 3+ Restrictions During Morning Peak in Northern Virginia

Evaluation

Performance evaluation is the analysis and manipulation of data to determine the conditions and effectiveness of the TMS. Different techniques, such as before-and-after comparisons and trend analyses, can help TMCs assess their performance and the ultimate results of their work.

Data analysis methods are an important part of performance evaluation. Agencies should consider the following criteria when selecting an analytic tool to evaluate their systems:

- Identification of the analysis context for the task at hand (i.e., planning, design or operations/construction).
- Determination of the appropriate geographic scope or study area for the analysis, including isolated intersection, single roadway, corridor or network.
- Capability of modeling various facility types, such as freeways, high-occupancy vehicle (HOV) lanes, ramps, arterials, toll plaza, etc.
- Ability to analyze various travel modes, such as single-occupancy vehicle (SOV), HOV, bus, train, truck, bicycle, and pedestrian traffic.
- Ability to analyze various traffic management strategies and applications such as ramp metering, signal coordination, incident management, etc.

- Capability of estimating traveler responses to traffic management strategies including route diversion, departure time choice, mode shift, destination choice and induced/foregone demand.
- Ability to produce direct output performance measures such as safety (crashes, fatalities), efficiency (throughput, volumes, vehicle-miles of travel (VMT)), mobility (travel time, speed, vehicle-hours of travel (VHT)), productivity (cost savings) and environmental (emissions, fuel consumption, noise).
- Tool/cost effectiveness for the task at hand, mainly from a management or operational perspective. Parameters influencing cost-effectiveness include tool capital cost, level of effort required, ease of use, hardware requirements, data requirements, animation, etc.

Although there are numerous methods to analyze the data, this subsection focuses on the more successful and frequently practiced techniques. These techniques include before-and-after evaluations, benefit-cost evaluations, analysis of trends, and comparison group evaluations.

Before-and-After

The most common method to evaluate the effectiveness is the before-and-after evaluation. This methodology studies the transportation network before and after the implementation of the new strategy or system. The same performance measures are used in the "before" and "after" conditions. An example of this type of evaluation is a study on the use of a strobe light in the red lens of a traffic signal. The purpose of the strobe light in this system is to draw the driver's attention to the traffic signal. The before-and-after study helped determine if this new technology prevents accidents. The *Freeway Management and Operations Handbook* identifies several limitations to this evaluation method. These limitations include:

- Difficulty in distinguishing the effects of an individual improvement when multiple improvements were made at one time.
- Time required for drivers to adjust their travel behavior after the system or strategy is implemented. Thus, the true effects of the changes may not be measured if the "after" data are collected too soon.
- Susceptibility to errors caused by time-related factors because of the often long time lag between the "before" and "after" condition.
- Fluctuation of a performance measure over time until an extraordinary value is observed, which causes the performance measure to return more typical values. This tendency is called regression to the mean. If the "before" or "after" condition exudes this tendency, it hides the true performance of the system.

Trend Analysis

A prerequisite to trend analysis is that the data must be archived. As a result, trends can be identified over time by graphical means or other statistical functions. An example is the INFORM system in Long Island, New York, and the way it tracks the percentage of devices online and maintains a trend analysis. This type of analysis is also beneficial because it indicates which aspects of the problem are benefiting from the investments made in the system.

Comparison Group Evaluation

This type of evaluation creates a comparison group with untreated sites, making it a control for other factors in the evaluation. This method makes it easy to see how effective the strategy or new technology is

at accomplishing the objective. Often, this comparison group is then applied to the before-and-after evaluation.

Root-Cause Analysis

Root-cause analysis is performed after an error occurs while collecting data, such as a loop detector producing incorrect readings. RCA determines the data collection problem so that it can be corrected. Prior to performing this type of analysis, it should be confirmed as being cost beneficial. It is ineffective to determine indefinitely the root cause of the occurrence. General causes, like operator error, should not be investigated, however, as the purpose of this analysis is to fix the problem. There are four major steps to this analysis, as shown in Box 4.

Data collection: The purpose of this step is to gain more information about and understand the event that is being investigated. Most of the time spent gathering data is for analysis.

Causal factor charting: Causal factors are "those contributors (human errors and component failures) that, if eliminated, would have either prevented the occurrence or reduced its severity." The final product of this step is a sequence diagram with logic tests that describes the event leading up to the occurrence. Figure 6-6 shows an example of this sequence diagram, where the cause of an imaginary accident is examined. Preparation of this chart by drawing a simple skeleton of the diagram should begin as soon as information is gathered about the occurrence. As more information is learned about the occurrence, more details are then added to the chart. This chart drives the data collection process by narrowing down which information is relevant and should be collected. Once the investigators are satisfied with their final product, they can continue on to the next step. Often, however, more than one causal factor associated with an occurrence exists. It also impossible that the agency did not identify some of the causal factors, causing the occurrence to repeat itself.

Root cause identification: Once all the known causal factors are identified, then the root cause can be determined. This step involves creating a root cause map, which "structures the reasoning process of the investigators" by addressing questions about why certain causal factors occur. In the end, this process determines the reason for the occurrence.

Recommendation generation and implementation: Recommendations that address the problem or root cause are generated in this step. These recommendations must be feasible and achievable by the agency. Implementing the recommendations so that the problem will stop and more accurate data will be generated is also an important element of this step.

Box 4: Steps for Root-cause Analysis (Rooney and Heuvel 2004)

Benefit Analysis

Benefit analysis uses statistics to determine whether and how the implemented project positively contributes to the intended audience and the overall system. The benefit-cost analysis is the recommended practice to describe the system benefits to the public and decision makers. At the regional level, the benefit-cost analysis will allow the system to be evaluated against traditional transportation program needs. The most practiced benefit analysis is benefit-cost evaluation.

This technique is the most widely accepted methodology for evaluating transportation improvement alternatives. The analyst must assign values to possible benefits and disadvantages of the system (such as shorter travel time or increased congestion). The analyst should consult an operations practitioner to ensure that the full range of benefits is captured. By analyzing the alternatives with respect to system costs, the analyst can determine objectively which offers the best benefit-cost ratio. The formula given by the *Freeway Management and Operations Handbook* is:

$$B/C = (\text{benefit of alternative i})/(\text{cost of alternative i})$$

If the benefit of the alternative is greater than the cost, then the improvement in the system is economically justified. This ratio provides a convenient basis for comparison of each alternative.

An incremental benefit-cost analysis should be used if the cost, quantities, and complexities of the alternatives' components build upon each other. For this approach the benefits and costs should be analyzed in terms of additional benefits achieved and costs incurred over the next expensive alternative. Doing so determines whether an investment necessary to achieve the next incremental step in the system can be justified in terms of the incremental benefits that would be achieved.

The downside of this method, however, is that not all benefits are easily quantified and not all quantifiable benefits can be converted into monetary value. One solution to this problem is to use utility-cost analysis. The utility-cost analysis assigns a weight to each goal and subgoal. Then, each alternative is rated based on the utility of each alternative in satisfying each goal and subgoal. Then, by applying the following formula, the utility can be calculated:

$$\text{Utility} = \Sigma \text{ Weight of goal} * \text{rate of goal}$$

The utility-cost ratio can be determined with the following formula:

$$U/C = (\text{Utility of alternative i})/(\text{cost of alternative i})$$

Reporting

Reporting allows for communicating valuable information about the TMS with the stakeholders, decision makers, and the public. These stakeholders can include (but are not limited to) government officials, agency management, and agency staff. This communication link is achieved by analyzing and interpreting the meaning and significance of the information into terms that are understandable by the audience. Good performance reporting focuses on a few critical aspects of the performance of the system and explains why these attributes of the performance were chosen to report.

Audience

Reporting needs for various stakeholder groups are often different, so they should be linked to previously established goals and objectives. Stating goals and performance expectations show the relation of the results through either visual or written information.

For those stakeholders in management or government positions, the report should communicate the current program status, future plans, and ways for the program to proceed. The public, however, is more interested in areas such as the acquisition and use of resources, service efforts, and accomplishments. One way to illustrate these accomplishments is to relate the results to the capacity to meet or exceed the current

performance expectations. The public is also interested in any risks that it may be susceptible to as a user of the system. Thus, it is good practice to explain what the key risks are, the level of the risks, and how the risks influenced any choices made in relation to policy, goals, and performance expectations.

One way to communicate transportation information to the public is through the media. Releasing the results of traffic and other related studies to the press has proven an effective way to increase public awareness. For example, the National Transportation Operations Coalition (NTOC) released its first National Traffic Signal Report Card in April 2005. This study used the results of a traffic signal system survey to give national grades from A to F in six distinct categories related to traffic signals. To raise awareness about the results—traffic signals are not being used to their full potential—the NTOC released the study findings through various media channels and held a national press conference in Washington, DC. By disseminating information through the media, officials can thus reach many more people with important new developments in transportation.

In addition to disseminating information to the public, reporting is also important to several activities within a TMS agency. These activities include planning, designing, operations and enforcement. The report related to any of these specific activities provides crucial information that could help improve the quality of the activities themselves.

The people responsible for reporting usually spend a considerable amount of time on structuring—formatting and publishing performance measurement results in the form of written and electronic reports. A major resource in planning a system is the information gained from long-term travel trends and infrastructure projects. They utilize some of the aforementioned analysis techniques, such as benefit-cost evaluation, to determine the appropriate applications that should be implemented in the system.

One primary purpose of performance reporting is to help manage operations. Most performance measures capture information related to everyday operations (MTG 2004). This information usually includes information on traffic data, such as traffic congestion (Kwon 2004). Reporting information about these operations relays information to the audience on what is currently being done by the audience and how well it is doing.

Law enforcement is an integral part of any transportation system. The enforcement agencies often are considered stakeholders for a system. They help promote safety within the transportation system. Thus, numerous performance measures relate to the operations of these enforcement agencies (such as response time). By reporting the results from these performance measures, these agencies can determine what areas under their purview need improvement.

Content and Frequency of Reporting

There are two types of reports that TMSs use to communicate information: internal reports and external reports. Internal reports stay within the agency and communicate information to different staff members. External reports, on the other hand, convey to audiences outside the agency how successful the agency is at accomplishing its mission, goals, and objectives in the context of "potential significant decision making or accountability implications."

There are several trends among agencies on how to report information. One trend is to post the report on their intranet sites. These types of reports are disseminated on a more frequent basis, such as weekly, monthly, or continually. To make some information accessible to a broader public, many agencies also

choose to post data via the Internet. One example is the Washington DOT's *Gray Notebook*. These types of reports tend to be generated either monthly or quarterly. Agencies also tend to generate more formal reports biannually or annually for their government and business stakeholders. These formal reports are those most commonly used among agencies. These types of reports include annual reports, business plans and other bounded reports. To keep managers and CEOs knowledgeable about the system, many agencies produce executive and mid-management reports. These reports can be produced in printed or electronic form. They do not need to be created with any particular frequency, but rather, depend on how often the executive members would like them. They vary from weekly to annually. "Notebooks" are another trend in reporting. The purpose of a notebook is to ensure that key decision makers are up-to-date on the goals of the program and its progress. Notebooks tend to be updated every month or quarter.

Best Practice: WSDOT

Washington Department of Transportation is one of the leading agencies in terms of public communication. Their quarterly performance report is called *Measures, Markers, and Mileposts,* also known as the "Gray Notebook." The Gray Notebook explains the agency's planning process and the rationale behind different actions. It also assesses the effectiveness of the statewide system. It tracks a variety of performance and accountability measures for routine review by the Transportation Commission. The Gray Notebook also is continually evolving and has become an important source of information about department performance for the CEO, state legislators and other agency stakeholders. These reports engage the reader and make data more readily accessible to the audience. There are several criteria that this report abides by, which are:

- Avoid colors; make the chart work in black and white.
- Use plain English and avoid jargon.
- Show only relevant data and remove "chart junk" (outline boxes, lines, colors).
- Cite data sources.
- Eliminate legend boxes and use pointers to label data.
- Drop extra grid lines and numbers and lighten line values.
- Avoid 3Ds; don't do multidimensional graphs.
- Use clear chart title and subtitles to explain the x-axis and y-axis, content, and purpose.

The Gray Notebook contains an array of information about the agency. The report is divided into two sections: the *Beige Pages* and the *White Pages*. The *Beige Pages* is a project delivery performance report that summarizes the project and the associated financial information. The *White Pages* gives three types of updates: annual performance topics, quarterly performance topics and special topics. Annual performance topics include pavement conditions, congestion and bridge conditions. The specific topics relevant to TMSs include:

- Traffic Fatalities:
  - Comparing Fatal and Disabling Crashes and Vehicle Miles Traveled (VMT).
  - Fatality Rate per Capita.
  - Fatality Rates Compared to National Average.
  - Seatbelt Use.

- Pavement Assessment:
  - Pavement Condition Rating.
  - Washington Pavement Roughness vs. Other States.
- Highway Maintenance.
- Incident Response:
  - Total Number of Responses by Month.
  - Number of Responses to All Incident by Time of Day.
  - Clearance Time by Response Mode.
  - Training Incident Responders.

Quarterly performance topics include highway construction, worker safety, incident response, Washington State ferries and Amtrak cascades. The specific include:

- Washington State Ferries:
  - Total Number of Complaints per 100,000 customers.
  - Common Complaints Rate per 100,000 customers.
  - Trip Reliability.
  - On-time Performance.
  - Ridership and Revenue.
  - Fare Box Recovery.
  - Terminal and Vessel Preservation Performance.
  - Capital Expenditure Performance.
- State-supported Amtrak Cascade:
  - Monthly and Annual Ridership.
  - On-time Performance.
  - Fare box Recovery.
  - Grain Train Carload.

Special topics include special events and innovations. Specific topics found in their 2004 report included:

- Oversize and Overweight Permits:
  - Non-electric Permits Turn Around Time.
  - Motor Vehicle Permit Revenue.
  - Pre-audit of Projects:
    - Highway and Ferry Programs.
    - Capital Management Project.
    - Environmental Programs.

Best Practice: VDOT

As a part of an upcoming build of the Virginia DOT's Archived Data Management System (ADMS) Web site, a daily report will provide transportation officials with a summary of the previous day's freeway traffic conditions in a metropolitan region (Evanchik 2005). For instance, the report gives updates on freeway mobility, number of incidents and traffic sensor availability from the previous day using graphs and maps. Below (Figure 6) is an example of the first page of the report.

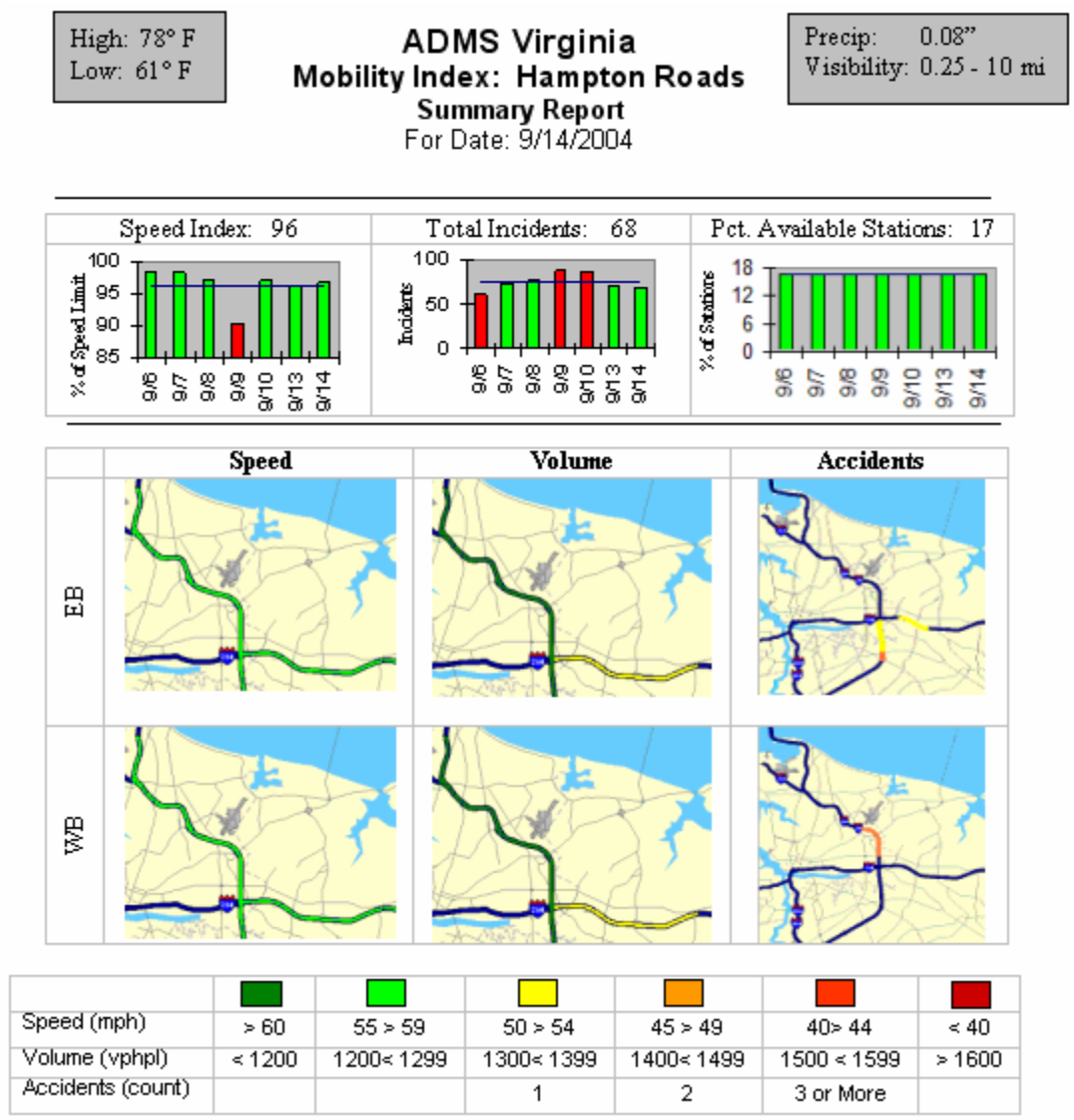

Figure 6: Example Report Page from ADMS Web Site (Evanchik 2005)

Due to the popularity of the Internet, most reports are available online. Reports also are commonly published electronically on a CD-ROM. A key factor for reporting these results is that the information must be presented in a manner for the audience to understand and interpret. NCHRP Synthesis 311 advises that reports combine written text (9 percent), tables (37 percent), charts (24 percent) and maps (24 percent).

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Transportation Management System Performance Monitoring, Evaluation, and Reporting

A Primer for Practitioners

Federal Highway Administration

U.S. Department of Transportation

1200 New Jersey Ave., N.E. (HOP)

Washington, DC 20590

Toll-Free "Help Line" 866-367-7487

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