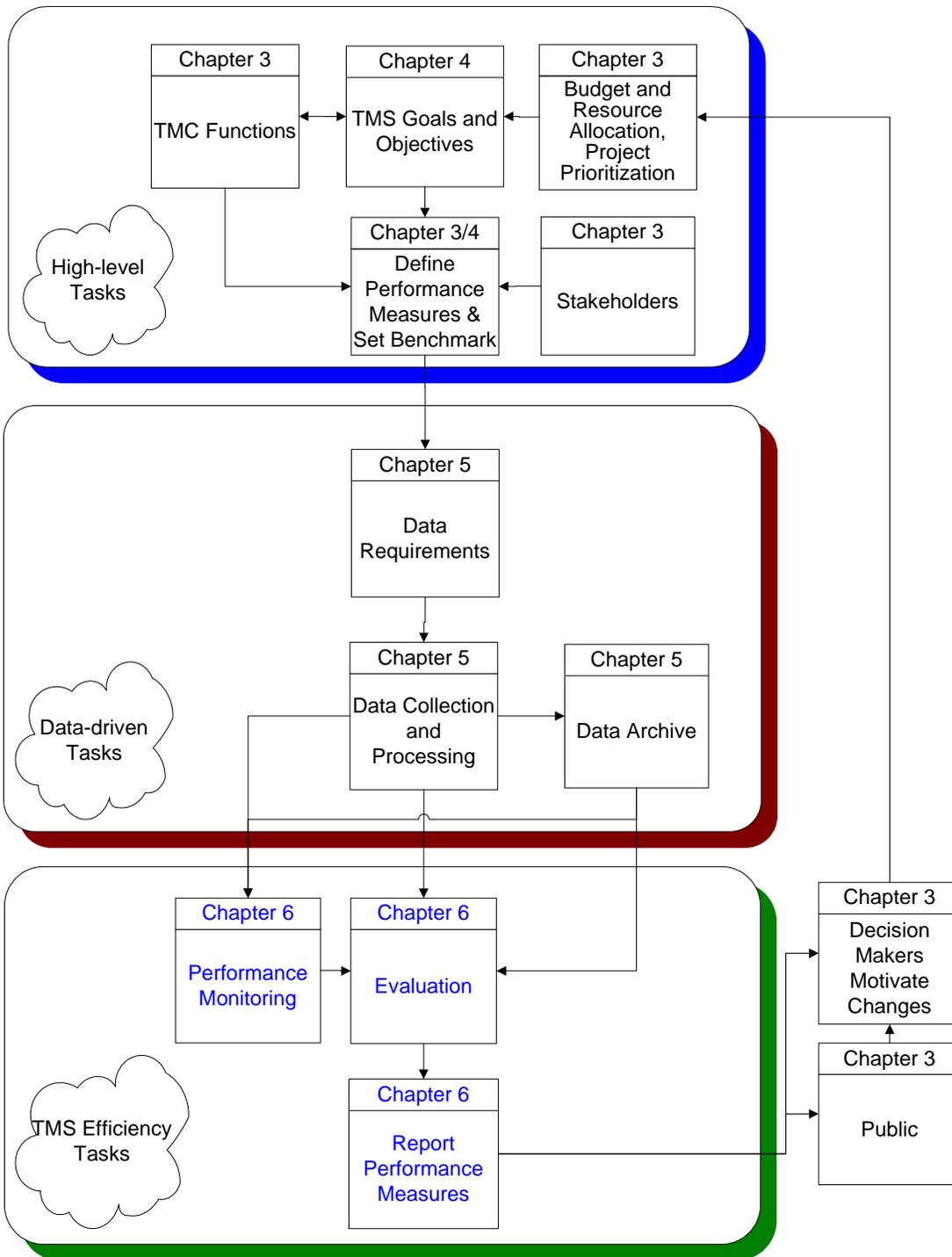


## CHAPTER 6. PERFORMANCE MONITORING, EVALUATION AND REPORTING

*Chapter Purpose:* This chapter provides (i) data analysis methodologies and processes related to performance monitoring and evaluation, (ii) various reporting techniques, formats and frequencies for TMS performance reporting and (iii) best practices on the TMC performance monitoring, evaluation and reporting. This handbook section deals with performance measures that use collected and archived traffic data, providing a more detailed discussion of performance monitoring, evaluation and reporting than that in Chapter 2. Chapter 7 then gives TMCs a self-assessment tool to gauge their performance measurement plans.

### **6.1 Overview of Performance Monitoring, Evaluation and Reporting**

Figure 6-1 illustrates the flow of this handbook and highlights the topics for this chapter—performance monitoring, evaluation and reporting. Performance monitoring and evaluation are related to topics discussed in Chapter 5 as the data are used for these processes. Reporting is related to evaluation because the information obtained from the data analysis is reported to the public and decision makers.



**Figure 6- 1: Outline of handbook**

As discussed in Chapter 2, performance monitoring, evaluation and reporting are the three crucial functions for the performance measurement program implementation. The outputs of these three functions ultimately determine the efficiency of the TMS. To review, these processes are defined as:

- **Performance monitoring:** Examines the actual system condition through observed data
- **Evaluation:** Analyzes the collected data and compares the results to benchmark performance measures
- **Reporting:** Provides information via various media to decision makers and the public

The function outputs and some important associated techniques are discussed in detail later in this chapter.

### *Performance Monitoring*

Performance monitoring allows for the agency to visualize the system status through certain measures. It provides “current information on the condition and service level of the transportation system” (Cambridge Systematics, Inc. 2004) for the operational level personnel of the agency (e.g., the operators and supervisors). This definition certainly can be expanded to the TMS. This up-to-date information is then used by the agency to make immediate decisions. Furthermore, long-term monitoring (via archived data analyses) provides significant information to assist in planning future maintenance as well as future deployment decisions.

There are different levels of monitoring for each level of management within the agency. While the operators of the system may focus on the day-to-day operations on one section of a corridor or highway, the supervisor may focus on several corridors or the entire region. Managers generally monitor entire systems based on the high-level information provided in daily or weekly reports.

### *Evaluation*

Evaluation refers to the analysis of data, which involves “comparing the results with established performance measures, and assessing the performance of the strategies, policies, systems, and operator procedures that comprise the program” (FHWA 2003). Evaluation allows for the assessment of program effectiveness, identification and justification of areas for improvement and support of requests for additional resources.

TMS initiatives are “planned, designed, deployed, operated, and maintained with public funding” (FHWA 2003). Thus, it is of utmost importance to ensure that these funds are spent efficiently. Evaluation allows for the following actions:

- Determination of the actual improvement in performance
- Identification of problems that result in inefficient system performance
- Analysis and prioritization of alternative solutions
- Estimation of the benefits and costs of the TMS.

Evaluation is an ongoing process that occurs throughout the life cycle of a TMS. Some methods to aid the evaluation process include before-and-after studies and benefit-cost estimates, which are discussed in subsequent sections of this chapter.

## ***Reporting***

A good performance measurement program improves communication with decision makers and other agencies involved with the operation and management of a transportation system. Improving communication and tracking progress is possible through reports distributed to internal and external stakeholders, delineating relevant performance results that will aid decision making (FHWA 2003). Reporting practices also create a sense of internal accountability to the performance management program, as employees must meet deadlines for providing updated tracking data (TransTech Management 2003).

Though reporting techniques may differ, reports should clearly and concisely communicate results. The content and context of a report will depend on its purpose, however, the information must provide “a quantity and format suitable for the intended audience” (TransTech Management 2003). Often, different reports are generated for the various audiences the agency is serving. For external audiences a report is “a highly polished document, while internal documents may be more informal” (TransTech Management 2003). Regardless, reports must be presented in a comprehensive manner and should thus include visual displays of data that show trends, performance and data interactions. The frequency of publication varies from weekly to annually, but annual reports are the most common (Transportation Research Board 2003).

## **6.2 Performance Monitoring**

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. (FHWA 2003).

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 6-2 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.

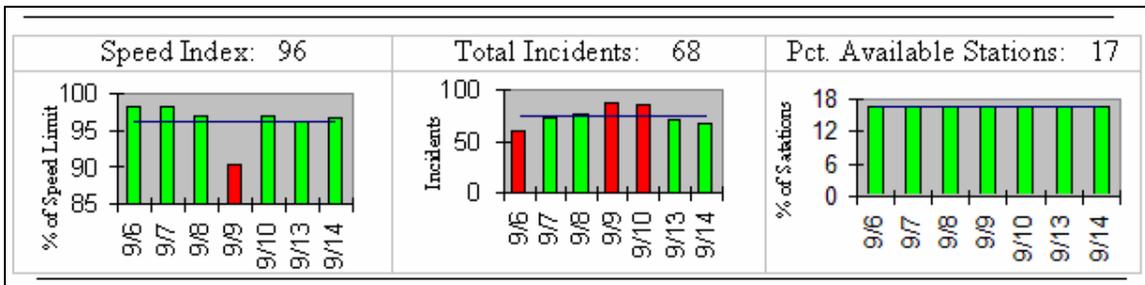


Figure 6-2: ADMS daily report graph examples

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 6-3 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, thus providing the public with valuable, real-time traffic conditions at points around New York City.



Figure 6-3: 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 6-4 exhibits the TMC's real-time map, which reports the current speed on any given section of highway or freeway.



Figure 6-4: 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 6-5 shows a typical data table from this HOV daily report.

Time Period	Outside Beltway 70-Newington (S)				Inside Beltway 90-S of Washington Blvd			
	Monday 06/27/05		May (Mon-Fri)		Monday 06/27/05		May (Mon-Fri)	
	Volume	Speed	Volume	Speed	Volume	Speed	Volume	Speed
5:00 AM - 5:15 AM								
5:15 AM - 5:30 AM								
5:30 AM - 5:45 AM								
5:45 AM - 6:00 AM								
6:00 AM - 6:15 AM								
6:15 AM - 6:30 AM								
6:30 AM - 6:45 AM								
6:45 AM - 7:00 AM								
7:00 AM - 7:15 AM								
7:15 AM - 7:30 AM								
7:30 AM - 7:45 AM								
7:45 AM - 8:00 AM								
8:00 AM - 8:15 AM								
8:15 AM - 8:30 AM								
8:30 AM - 8:45 AM								
8:45 AM - 9:00 AM								
9:00 AM - 9:15 AM								
9:15 AM - 9:30 AM								
9:30 AM - 9:45 AM								
9:45 AM - 10:00 AM								

	Volume (veh per 15 min)	Speed (mph)
	< 750	> 55
	750 - 900	45 - 55
	> 900	< 45
	Data not available	Data not available

Figure 6-5: Analysis for HOV 3+ restrictions during morning peak in Northern Virginia

### 6.3 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 and trend analyses, can help TMCs assess their performance and the ultimate results of their work. This section addresses various evaluation techniques and ways that TMCs use them for self-assessment.

#### 6.3.1 Statistical Analysis and Comparison

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 plazas, 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, ability to automate all or part of the process, etc. (FHWA 2003).

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.

#### *6.3.1.1 Before-and-After Evaluation*

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 (FHWA 2002). 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 (Cottrell 2005). The Freeway Management & 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.

Box 6-1 highlights a best practice case in which San Antonio TransGuide used the before-and-after analysis to evaluate their data.

**Box 6-1: Best Practice of Before-and-After Analysis (Henk 1997)**

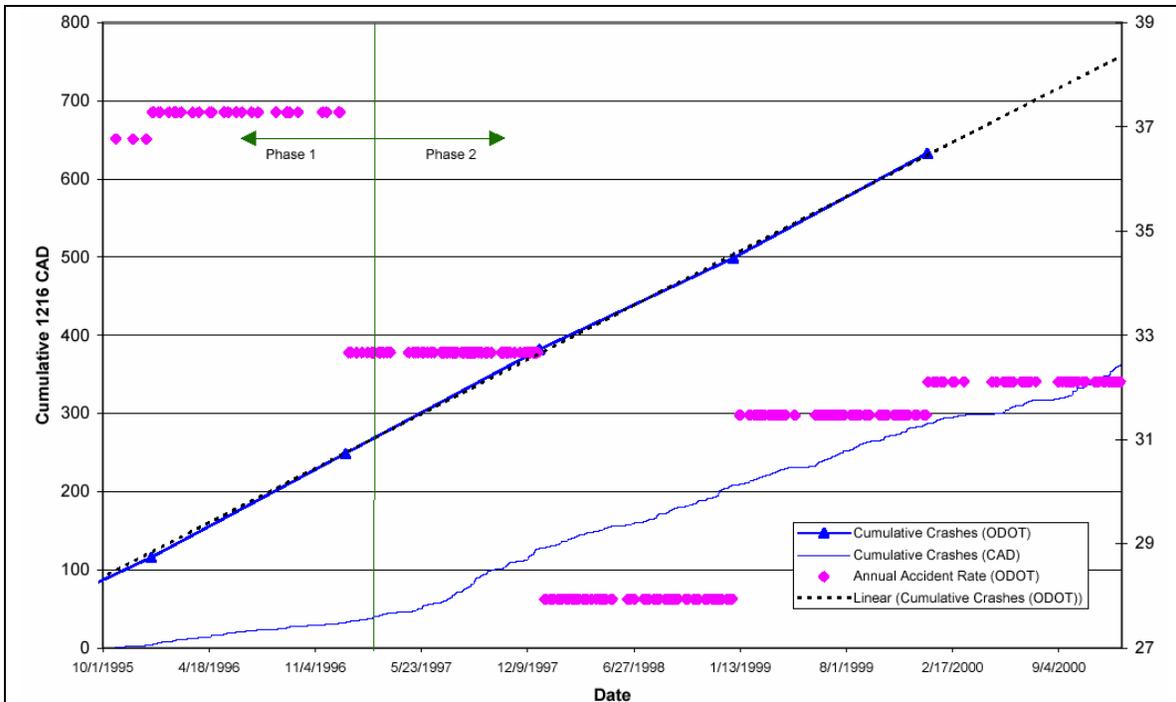
**Best Practice:** An example of this type of study was performed by the San Antonio TransGuide. There was a report created in 1997 by Russell Henk et al. entitled “*Before-and-After analysis of the San Antonio TransGuide System*”. This paper documents the impact of the system on crashes and incident response times during the first five months of operation and reports the findings of a survey investigation into driver response to the TransGuide system. Compared to the time period when the system did not exist, the study found that the system reduced primary accidents by 35 percent, reduced secondary accidents by 30 percent, reduced inclement weather accidents by 40 percent and reduced overall accidents by 41 percent.

*6.3.1.2 Analysis of Trends*

A prerequisite to trend analysis is that the data must be archived so that 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 (Baxter 2002). This type of analysis is also beneficial because it indicates which aspects of the problem are benefiting from the investments made in the system. Box 6-2 illustrates a best practice of trend analysis performed by Oregon DOT.

**Box 6-2: Trend Analysis Best Practice (Bertini 2001)**

**Best Practice:** The Oregon DOT performed a trend analysis with its incident data. These data were filtered, and trends were studied over time. An example of the results from this analysis is shown below.



This graph compares the Highway 18 observed accident frequency from the computer-aided dispatch (CAD) data with the accident rates reported by the ODOT Crash Analysis Unit (referred to as ODOT data). It displays the cumulative numbers of filtered accidents between 1995 and 2000 for both data sources. This trend analysis is thus able to show the different results obtained by the two accident data collection methods. For instance, while the ODOT method yields a constant accident rate (slope of the cumulate crash line), the CAD method shows a significant increase in the accident rate around September 1997.

### 6.3.1.3 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.

#### Box 6-3: Comparison Group Analysis Best Practice (Minnesota Department of Transportation/SRF Consulting Group, Inc., 2002)

**Best Practice:** In 2002 the Minnesota Department of Transportation (Mn/DOT), with help from the Federal Highway Administration (FHWA), conducted a study of non-intrusive traffic data collection technology. Specifically, Mn/DOT evaluated nine different traffic sensors on various criteria, which included cost, performance, ease of setup, etc. The following table shows the study results.

Sensor Model	Technology	Freeway Test Site			Ease of Installation	Ease of Calibration	Reliability
		Speed Performance	Volume Performance				
			Peak	Off Peak			
Autosense II	Active Infrared	+	+	+	+/-	+	+
3M Canoga	Magnetic	+	+	+	-	+/-	+
ECM Loren <sup>(1)</sup>	Microwave			+	+/-	-	-
SmarTek	Passive Acoustic	+	+/-	+	+	+	+
ASIM IR 254 <sup>(2)</sup>	Passive Infrared (PIR)	+/-	+/-	+	+	+/-	+
ASIM DT 272 <sup>(3)</sup>	PIR/Ultrasonic	N/A	+/-	+	+	+	+/-
ASIM TT 262	PIR/Ultrasonic/Radar	+	+	+	+	+	+/-
Autoscope	Video	+	+	+	+	+/-	+
Traficon	Video	+	+	+	+	+/-	+

Notes:

+ Denotes a sensor that performed satisfactorily in the stated condition.

+/- Denotes a sensor that meets some but not all the criteria for satisfactory performance in the stated condition.

- Denotes a sensor that does not perform satisfactorily in the stated condition.

(1) The ECM Loren did not function in the test. No data available.

(2) ASIM IR 254 was difficult to calibrate for sidefire installation because of alignment complications.

(3) Data collection problem presented difficulty in fully evaluating the ASIM DT 272.

### 6.3.1.4 Root-Cause Analysis

Root-cause analysis (RCA) 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 the root cause of every occurrence. General causes, like operator error, should not normally be investigated because the purpose of this analysis is to fix the problem unless, however, operator errors are a chronic occurrence. In that case operational issues should be investigated (ex. Staff size, training, or work procedures). There are four major steps to this analysis (Rooney and Heuvel 2004):

1. **Data collection:** The purpose of this step is to gain more information about the event that is being investigated.
2. **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 is also possible that the agency did not identify some of the causal factors, causing the occurrence to repeat itself.

- 3. 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.
- 4. 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.

Documenting this process is important. This documentation can be achieved with root cause summary tables. Each column in the table represents an important step of this analysis process. The first column gives a general description of the causal factor, such as background information. The second column shows the path or paths through the root cause map associated with the causal factor. An example of the map is illustrated in Figure 6-7. Note that LTA states for less than adequate. The example also does not include all considered reasons. Refer to <http://www.asq.org/pub/qualityprogress/past/0704/qp0704rooney.pdf> to find a more detailed description of a root cause map. The third column identifies the recommendations associated with each root cause.

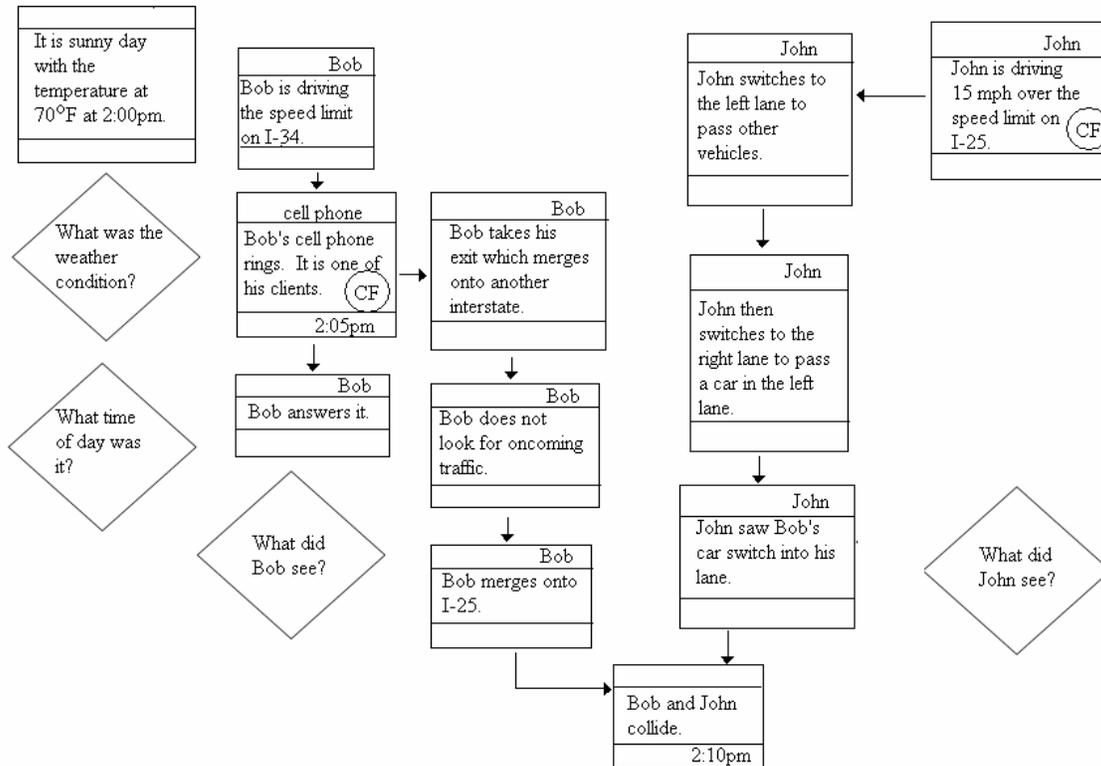


Figure 6-6: Causal Factor of an accident with John and Bob (Rooney and Heuvel 2004)

Table 6.1: Root Cause Summaries (Rooney and Heuvel 2004)

	Description	Paths Through Root Cause Map	Recommendation
Causal factor #1	Bob talks on his cell phone while driving	-Personnel difficulties -Standards, policies, or administrative controls LTA	-Implement policy of either using head set or refraining from using phone
Causal factor #2	John is driving 15 mph over the speed limit.	-Personnel difficulties -Standards, policies, or administrative controls LTA	-Have law enforcement monitor vehicle speeds more carefully -Have harsher punishment for violators

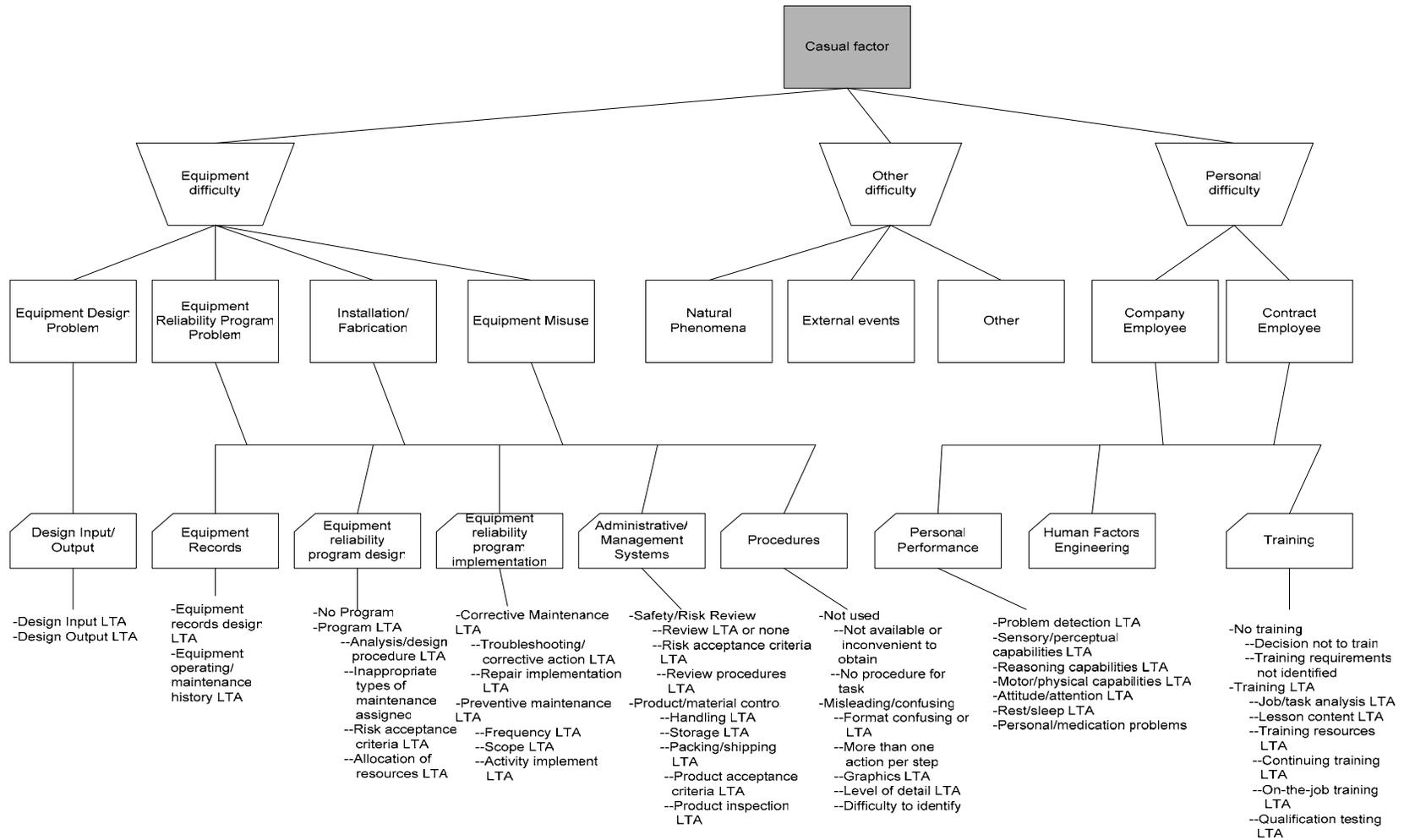


Figure 6-7: Root cause map example (Rooney and Heuvel 2004)

### 6.3.1.5 Benefit Analysis

Benefit analysis uses statistics to determine whether and to what extent 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 (Amodei 1998). The most practiced benefit analysis is benefit-cost evaluation.

#### *Benefit-Cost Evaluations*

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 & Operation 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 sub-goal. Then, each alternative is rated based on the utility of each alternative in satisfying each goal and sub-goal. 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:

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

Box 6-4 provides a best practice example for a benefit-cost analysis.

**Box 6-4: Benefit-cost analysis best practice (Sisiopiku 2005)**

**Best Practice:** In considering the application of a ramp metering system on freeways in Alabama, researchers in the Department of Civil and Environmental Engineering at the University of Alabama at Birmingham (UAB) conducted a benefit-cost analysis as part of their study. To assist in this analysis, researchers used the FHWA's ITS Deployment Analysis System (IDAS). This software package helps planners calculate the benefits and costs of potential ITS system implementations.

The Cost Module Report was the first part of the analysis. The initial, operations and maintenance costs of the ramp metering system were calculated. Using these values, the average annual system cost was determined for the installation and maintenance for the first 25 years of the system life cycle. The second part of the analysis is the Benefit Module Report formulation. Here, weights and monetary values for various relevant categories are calculated and given as an average annual benefit over the first 25 years. Figure 6-8 shows these categories and the results of the benefit-cost analysis”.

<b>BENEFITS/COST SUMMARY</b>			
<b>Project: Birmingham Ramp Metering</b>			
			<b>Ramp Meter (2005 US \$)</b>
<b>ANNUAL BENEFITS</b>		<b>Weight</b>	
Change in User Mobility		1.00	-
Change in User Travel Time		1.00	11,000
Travel Time Reliability		1.00	1,150,000
Fuel Costs		1.00	700,000
Accident Costs (Internal)		1.00	500,000
Accident Costs (External)		1.00	275,000
Emissions		1.00	
HR/ROG		1.00	9,000
Nox		1.00	35,000
CO		1.00	225,000
PM10		0.00	-
CO2		1.00	150,000
SO2		1.00	10,000
Global Warming		0.00	-
Noise		0.00	-
Other Mileage-Based External Costs		0.00	-
Other Trip-Based External Costs		0.00	-
Change in Public Agencies Costs		0.00	-
Other Calculated Benefits		0.00	-
User Defined Additional Benefits		0.00	-
<b>Total Annual Benefits</b>			<b>3,065,000</b>
<b>ANNUAL COSTS</b>			
Average Annual Private Sector Costs			-
Average Annual Public Sector Costs			208,000
<b>Total Annual Costs</b>			<b>208,000</b>
<b>BENEFIT/COST COMPARISON</b>			
<b>Net Benefit (Annual Benefit-Annual Cost)</b>			<b>2,857,000</b>
<b>B/C Ratio (Annual Benefit/Annual Cost)</b>			<b>14.7:1</b>

## 6.4 Reporting Practices

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 (Transportation Research Board 2003). 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 (GASB 2003).

Two important aspects within reporting are: (i) the audience, i.e., the stakeholders for whom the report is meant and (ii) the content and frequency of reporting. These two aspects are explained in the next two subsections.

#### **6.4.1 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 (Governmental Accounting Standards Board 2003).

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 (GASB 2003). 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 they 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 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 (*ITE Journal* 2005). 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 (MTG Management Consultants 2004). 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 (CDOT 2005).

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 on everyday information provides the audience with feedback on what it is doing and how well.

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.

#### ***6.4.2 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” (GASB 2004).

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 reported 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 (MTG Management Consultants 2004).

**Best Practice (WSDOT 2005):** 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.” This 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 Incidents 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. Specifically, they cover:

- Washington State Ferries

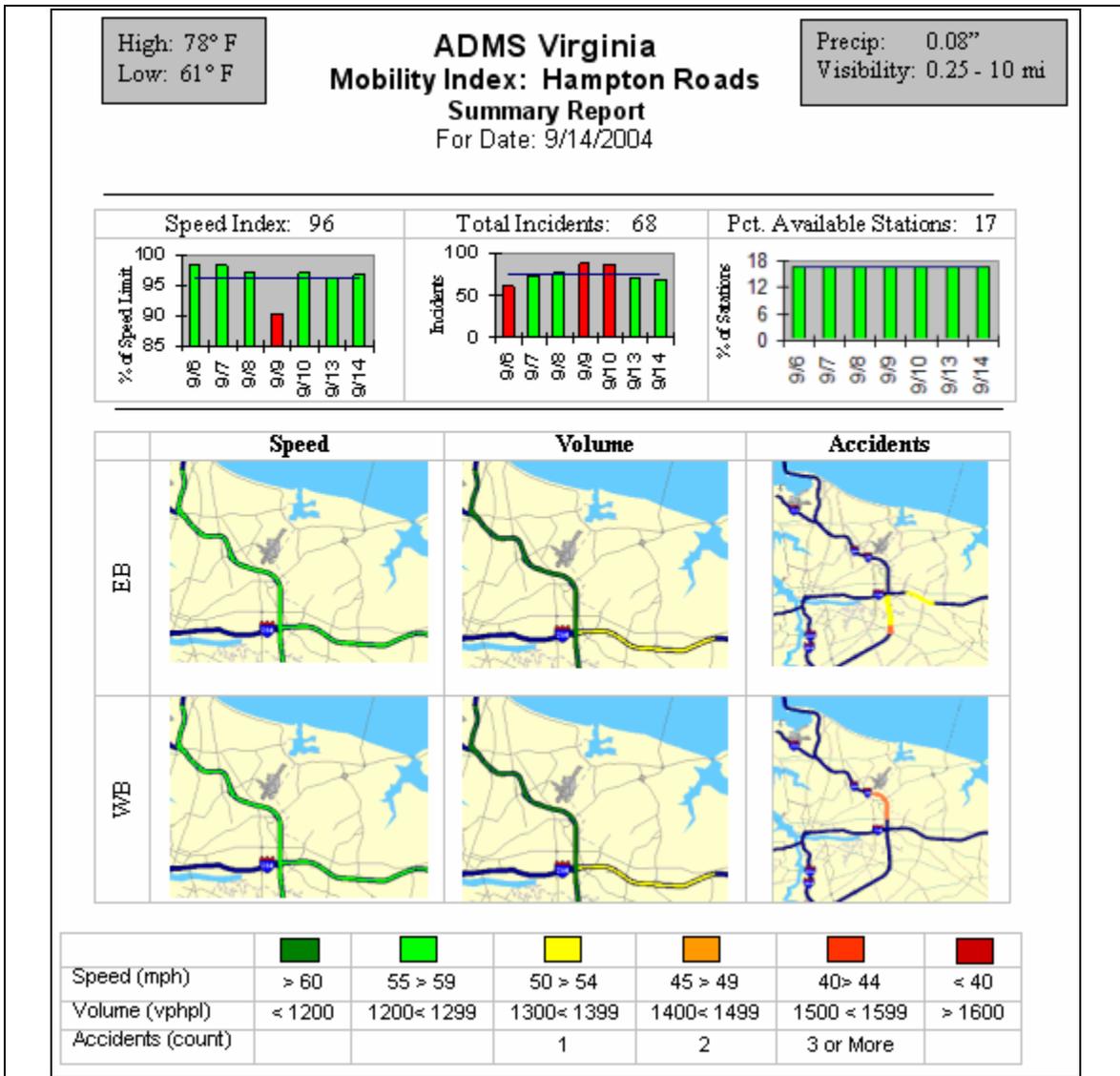
- Total Number of Complaints per 100,000 customers
- Common Complaints Rate per 100,000 customers
- Trip Reliability
- On-time Performance
- Ridership and Revenue
- Fare Box Recovery
- Terminal and Vessel Preservation Performance
- Capital Expenditure Performance
- State-supported Amtrak *Cascade*
  - 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
  - Nonelectric Permits Turn Around Time
  - Motor Vehicle Permit Revenue
  - Pre-audit of Projects
    - Highway and Ferry Programs
    - Capital Management Projects
    - Environmental Programs

**Box 6-5: ADMS Virginia Daily Report (Evanchik 2005)**

**Best Practice:** As a part of an upcoming build of the 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. 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 is an example of the first page of the report.



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 Report 311 states that reports combine written text (9%), tables (37%), charts (24%) and maps (24%). As charts and maps are very effective visualization tools for reporting, the next section presents some useful hints and practices on these elements.

### 6.4.3 Charts used in Reporting

Charts can include graphs such as histograms, line graphs and contour maps. The remainder of this section will discuss good examples of these charts.

#### *Histogram*

A histogram involves two discrete variables that are represented on a two dimensional graph. Figure 6-8 is an example histogram, which compares roadway incidents by location and year. Although the histogram is appropriate for this comparison because two discrete variables (location and frequency) are involved, a few problems exist in this example. First, it is difficult to distinguish which year some of the values apply to (such as 60 & 61). This problem is caused by the fact that a large range of frequencies exists with this specific chart. One solution would be to separate the data such that the frequencies for each chart have a smaller range of values. Another problem is that some of the locations only have values for one year. Thus, there is no point in a comparison for this location. These locations could then be omitted from the chart. Nonessential values of frequency also create a crowded feel to the chart and are difficult to read. In this case, because so many locations are represented, including the value may confuse the reader.

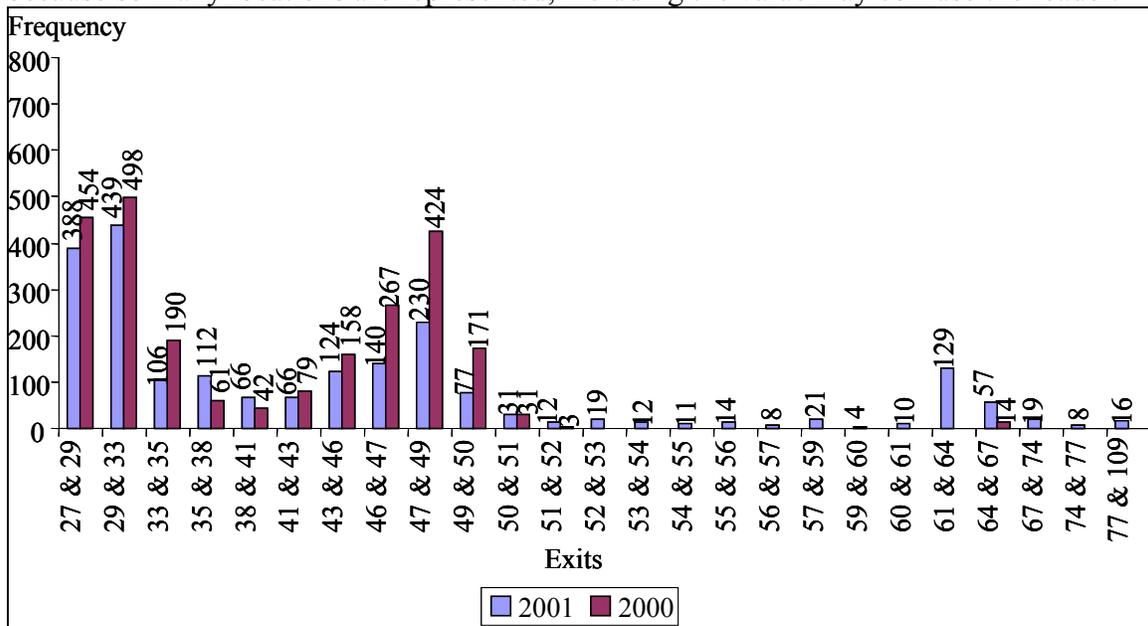


Figure 6-8: Comparison of incidents/disabled vehicles distribution by location

Figure 6-9 is another example of a histogram comparing two years. It provides data quality information for the years 2000 and 2001. The three-dimensional element improves the look of the graph. The specific percent is displayed in a horizontal manner, making it easier to read. The chart is streamlined and imparts essential information easily.

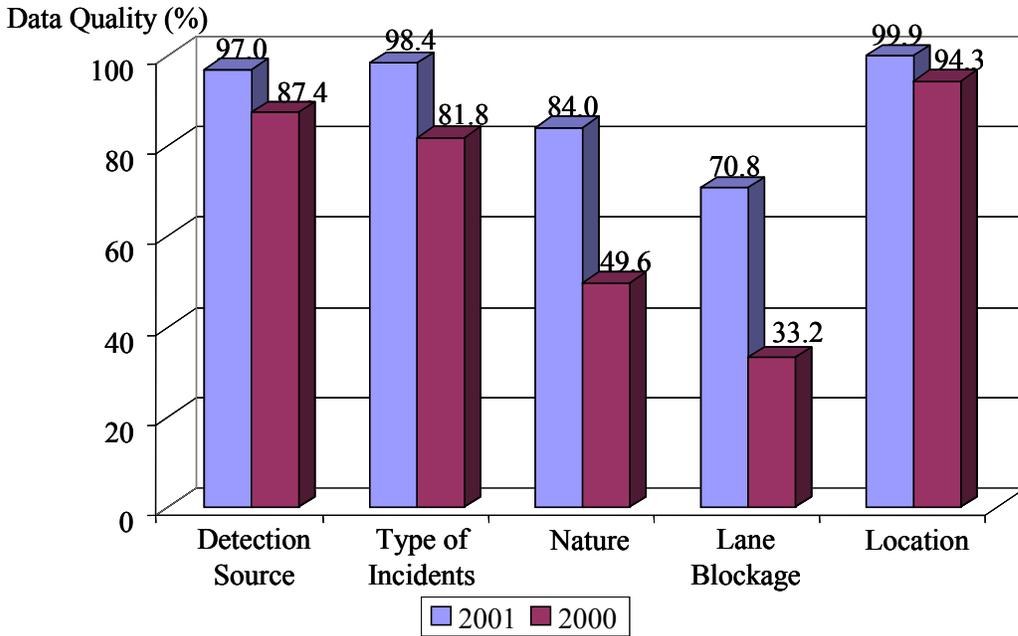


Figure 6-9: Summary of data quality based on all available reports (CHART)

*Line Graph*

A line graph involves one discrete variable and one continuous variable. Figure 6-10 is a line graph illustrating a trend among incidents occurring on secondary roadways. Although this graph is not busy and the values are easy to read, because there is no key, the reader would be unable to determine what the different lines represent.

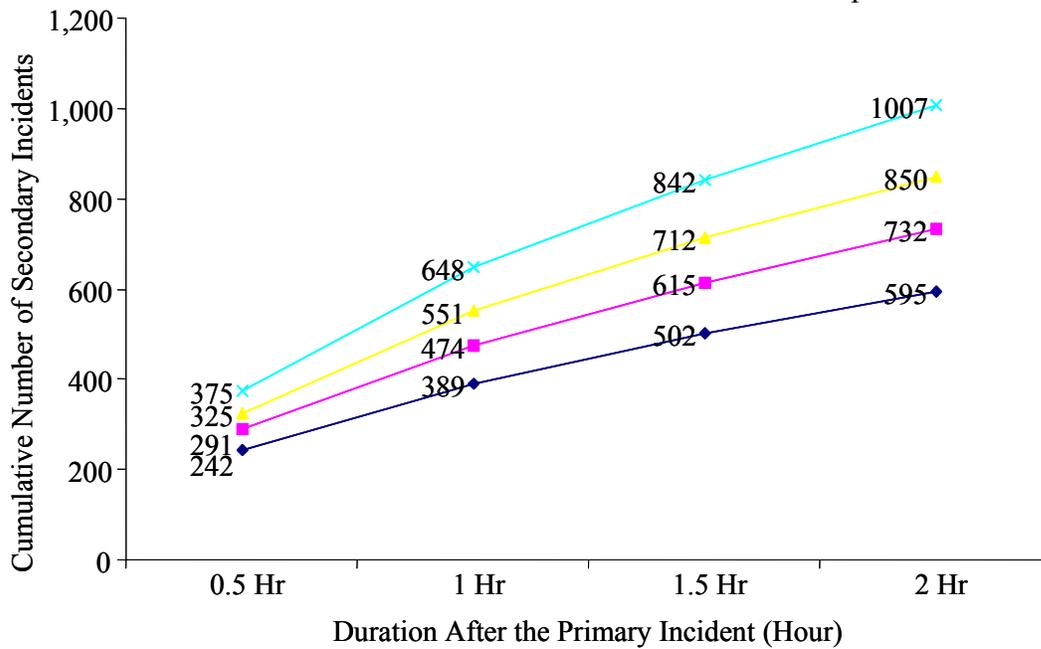
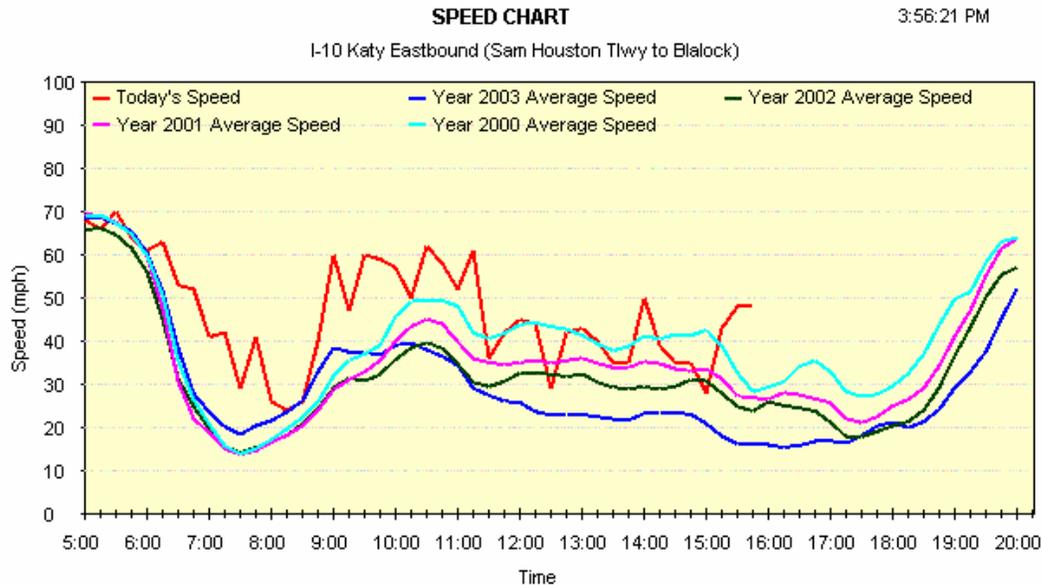


Figure 6-10: Distribution of reported secondary incidents

Figure 6-11, on the other hand, is an excellent line graph. Importantly, it includes a key, making it easier to understand. Also, since the values on the y-axis have a small range,

determining where individual values fall on the line is clear and simple. Both the x- and y-axes are labeled with the values they represent and the unit of measure (e.g., mph). Additionally, this graph is an appropriate choice because the agency can show the trends associated with speed for different years.

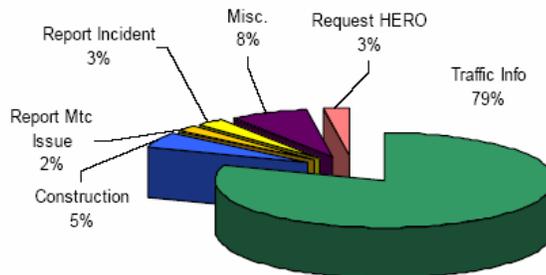


**Figure 6-11: Travel speeds in the I-10 Katy eastbound corridor**

*Pie Charts*

Pie charts illustrate how specific components comprise an entire system. For example, as seen in Figure 6-12, the pie chart shows the types of calls and the frequency of each type. This graph is a good example because, along with the visual of the pie chart, the precise percentage is listed. There are not too many types, so the graph is not too cluttered either.

**Calls by Type**



**Figure 6-12: Pie chart of calls by type**

Figure 6-13 has similar features as Figure 6-17, except this example also includes a table denoting the precise number of each type. The table data make clear the size of the sample.

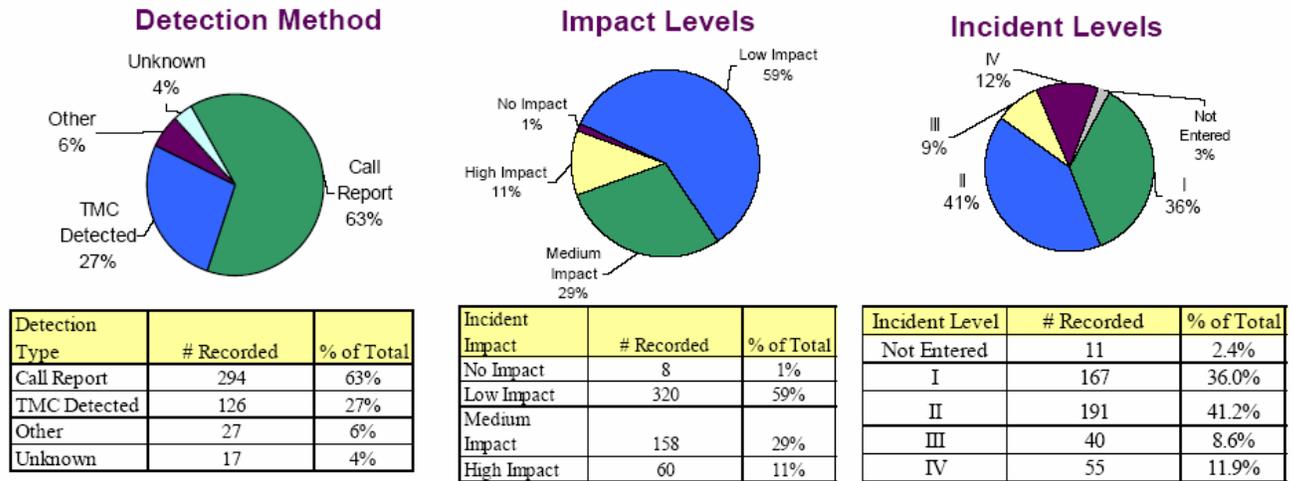


Figure 6-13: Pie charts with tables

*Other Chart Types*

A combination of a line graph and histogram can present a clear picture of congestion trends. Specifically, it can show when congestion usually occurs and its effects on vehicle speed and output. Figure 6-14 is a combination of a line graph and histogram. Here, the histogram provides the frequency of congestion, defined as LOS F, at the specified times. The line graph gives the roadway volumes and is color-coded according to vehicle speed. As a result of using these multiple display functions, this single graph provides a great amount of congestion information.

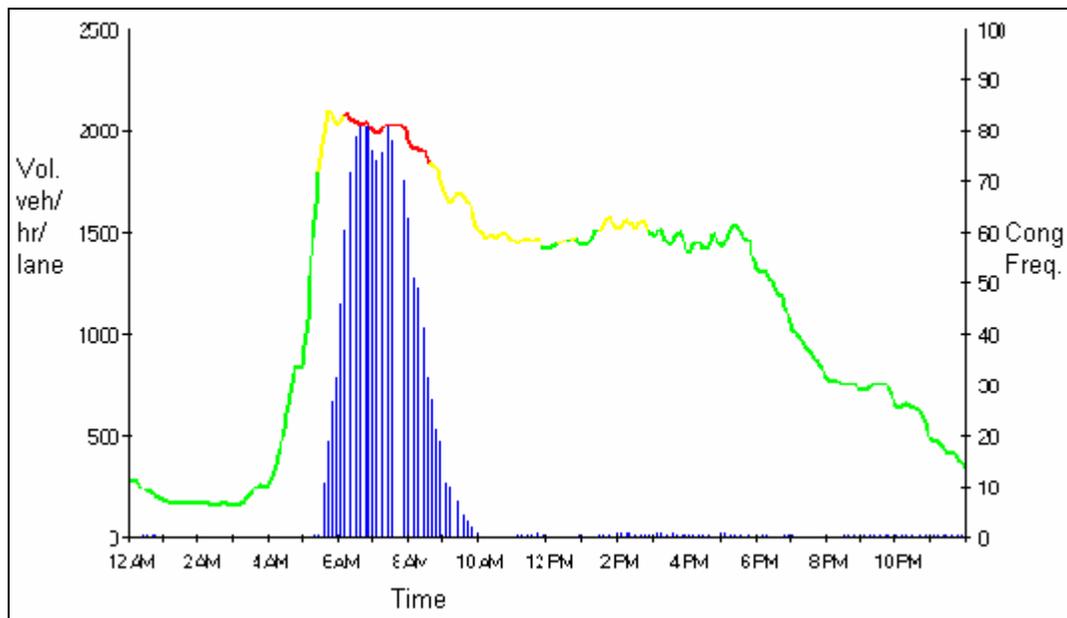


Figure 6-14: Estimated speeds, volumes, and frequency of congestion on I-5 near S. 184th St. in Washington in 2000 (Hallenbeck 2003)

Another effective way to illustrate congestion trends is to use a “temperature” diagram. These diagrams can be applied to specific corridors to show variations in congestion

based on direction, time of day, and severity. Figure 6-15 provides an example of a “temperature” traffic profile.

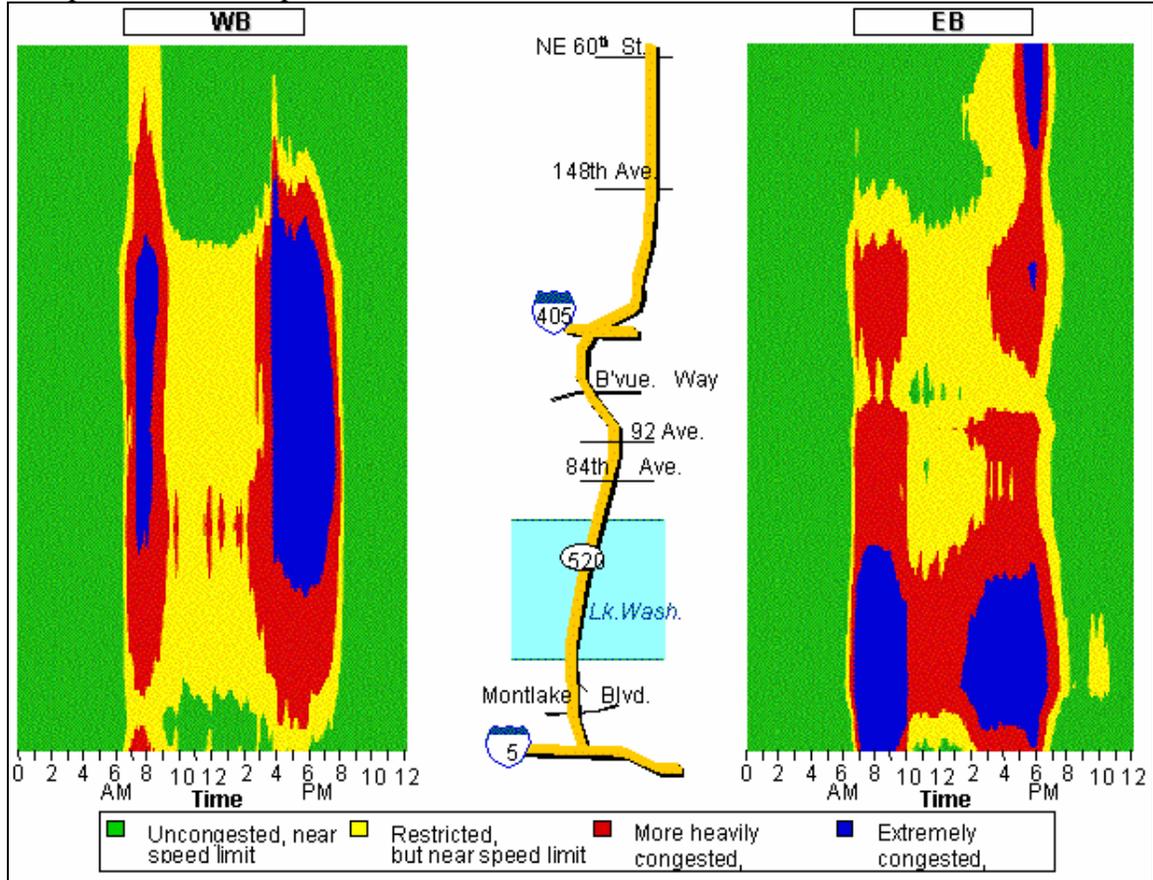


Figure 6-15: Traffic profile of general purpose lanes along Rt. 520 in Washington (HCM 2000)

## 6.5 Chapter Summary

This chapter presented and explained various methodologies that have been used (or can be used) in the TMS performance monitoring, evaluation and reporting. In addition, best practices in the applications of performance monitoring, evaluation and reporting methodologies were presented to help understanding the use of these in practice. The next chapter provides a self assessment tool that will help TMS/TMC managers assess and improve their TMS/TMS performance monitoring, evaluation and reporting.

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