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**COMPLETING THE CIRCLE: USING ARCHIVED OPERATIONS
DATA TO BETTER LINK DECISIONS TO PERFORMANCE**

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COMPLETING THE CIRCLE: USING ARCHIVED OPERATIONS DATA TO BETTER LINK DECISIONS TO PERFORMANCE

Executive Summary

This report summarizes current practices in using archived operations data to better link decisions to transportation system performance. The joint research team of PATH and TTI investigated data archiving and performance monitoring activities in selected locations, with a primary focus on the use of performance measures in improving operations. We first provide an overview of a traffic performance measures system and its components, then we summarize the major findings for each system component. The major findings and conclusions of our research are summarized below.

- **Better Utilization of Archived Data Will Take Time and Experimentation with Data**
Typically, the regions in which data archiving and performance monitoring are most prevalent and widespread are those in which local/state agencies have been archiving and analyzing data for at least 5 or 10 years. For example, the archived data in Seattle has been widely distributed for at least the past 5 years and has become somewhat institutionalized. This finding suggests that agencies in other regions may be likely to adopt archived data for performance monitoring once they 1) learn more about how much and what data is available from this “new” intelligent transportation system data source; 2) have the quality and use of that data demonstrated through practical applications; and 3) experiment with archived data to ensure that it meets their needs. It is hoped that this report may help TMCs build upon the experience of other TMCs, thus reducing the time needed to fully implement a performance measurement system based on archived traffic data.
- **Archived Traffic Data Should be Used to Improve Traffic Management Center (TMC) Performance**
This review of TMCs found that many view their mission solely as “crisis management.” Some see little connection between historical archived data and the crises they manage on a day-to-day basis. However, numerous other “operations-based” companies inside and outside of transportation make extensive use of “archived” operations data because their profits depend upon their ability to exploit that data to develop ways to operate more efficiently and effectively. For example, trucking and package delivery companies keep extensive records of package locations and times, and then analyze these shipping times to find locations of inefficiency. Similarly, TMCs should analyze performance data to determine the optimum way to manage crises and to develop other means of operating the transportation system at its maximum efficiency. Because most TMCs are already short of resources, more resources will be needed to meet this true operations mission.
- **The Key to Effective Data Archives Is Assignment of Responsibility and Adequate Funding**
Our review found numerous institutional models used in maintaining ITS data archives. One thing was clear: there are numerous uses of the data beyond any single workgroup or agency. To date, archived data are being used by operators, planners, researchers, air quality analysts, transit providers, consultants, media, and others. In most cases, however, the data were being maintained by operations personnel simply because they own the equipment that collected the data. In some areas, metropolitan planning organizations are preparing to fill the role of maintaining operational data archives (e.g., Dallas-Ft. Worth, Cincinnati, Detroit). In other areas, the state or local DOT has taken on this responsibility (e.g., California, Seattle, Houston, Atlanta, Phoenix). The determination of which agency maintains data archives has been highly dependent on existing institutional structures and relationships. Although there are many possible models, and it is not clear whether one model is better than the others. It is clear that an adequately funded organizational unit responsible for archiving and disseminating the data is essential to obtaining the full benefit from the traffic data that TMCs collect.

Introduction

Traffic Performance Measure System Structure

Operations managers collect traffic data in order to better manage traffic. But this information can also be used to measure performance. Performance measures have several potential uses. They can be used to measure the state of the system, the traffic volumes, the distribution of travel time and delay, vehicle emissions, and the safety of the facilities. This tells decision-makers where improvements are needed and where needs are greatest and thus can inform decisions regarding where to allocate resources and the total level of resources to seek.

Evaluating actual changes in operating strategies or capital improvements by comparing performance before and after provides a basis for estimating the effects of future actions. If “before and after” performance data are available, the performance of two different facilities can be compared and inferences made regarding the effects on performance of differences in operations, facilities or demand.

Even the traffic information used to inform travelers and manage traffic in real time can be thought of as performance measures. So performance measures can inform the decisions of travelers as well as system operators and people who plan operations, design facilities, develop capital programs, and allocate funds.

The process of creation and use of performance measures can be thought of a circle in which measures of traffic conditions are used to inform actions by the users and providers of transportation, which in turn, affect the traffic conditions. Figure 1 shows the components of a traffic performance measure system.

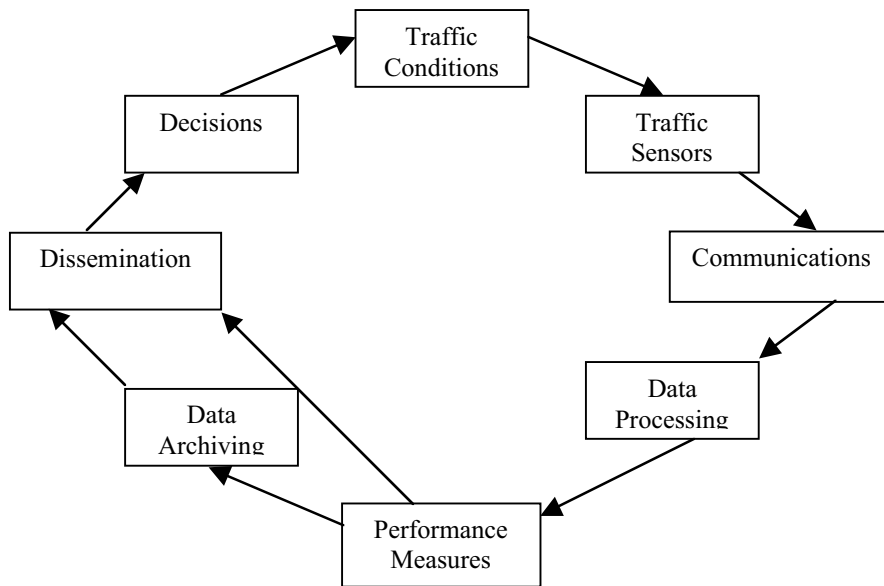


Figure 1. Components of a Traffic Performance Measures System

The traffic conditions are recorded by some type of sensor, which transforms what is sensed into a standard format that is recognized by the data processor. Some type of communication system sends the data to the processing location. The raw data from the sensors is processed into performance measures, ideally into multiple formats for multiple users. The performance measures are disseminated to users immediately or may be archived for later dissemination to users or retrieval by users. They then use the performance measures to make decisions that, in turn, affect traffic. This is the ideal. In most regions the circle is broken at some point for most, if not all, users. For a particular type of decision-maker the circle can break down at many points:

- there may not be functioning sensors at critical locations
- the communications may not be in place or may not be functioning properly
- the data processing may not include sufficient checks for errors and may not provide information in a useful form for all users

- data may not be archived for a long enough period
- dissemination methods may be inadequate
- decision makers may not have good tools or sufficient resources to fully utilize the performance measures for decision making.
- This paper will focus on the data collected by the TMCs in the course of managing operations. But the TMCs are not the only agencies that collect traffic data. Planning units of state departments of transportation, metropolitan planning organizations (MPOs), and local transportation agencies may also collect traffic data for their own uses. Although it makes sense for TMCs to share the data they collect in the course of managing operations, it should not be assumed that they should be responsible for meeting all traffic data needs. It may be more cost-effective for other organizations to sample some traffic data as needed than for TMCs to set up a permanent infrastructure to continuously collect all the data needed by all potential users.

Goals

The ultimate goal of the traffic performance measure system should be to provide measures needed to support decisions by the providers and users of the transportation system. Considering the current state of most systems, it may be more useful to define a more modest and immediate goal. We submit that this should be to consider the state of the circle described above, consider the value of the different uses of information, consider the costs of completing the circle for these uses, and develop an overall plan for and justification of investment in the system.

Organization of This Paper

This paper generally follows the circle shown in Figure 1, first discussing the decisions and the performance measures needed to inform each type of decision. Then various types of sensors, communications, and data processing tasks are discussed. In each section, the state of the practice is described. The report concludes with recommendations for improving the traffic performance measure system. Appendix A contains the case studies from which the state of the practice and recommendations are drawn. Because the major cost of improving the system is likely to be the installation and maintenance costs of sensors, Appendix B outlines a methodology for developing a traffic surveillance investment plan.

Decisions Informed by Traffic Performance Measures

As noted in the introduction, traffic performance measures can inform the decisions of several groups of people. Table 1 shows the different groups of potential data users. Although they use similar data, the format of the data will be quite different.

In many of the areas surveyed, performance measures were much more prevalent at the MPO or planning level than at the operations level. At the planning level, performance measures are used for investment analyses and project prioritization. However, a few of the operating agencies surveyed are using or are planning to use performance measures. For example, WsDOT produces an annual report of performance measures using archived operations data on major freeways. Caltrans has similar plans for performance measures using the Performance Measurement System (PeMS), and their archived operations data.

Travelers and Commercial Vehicle Operators

Travelers make decisions regarding departure time, route, mode, and destination as well as whether to travel or not. Although these decisions are based primarily on the activities the trip serves, the value of these activities, and the locations at which these activities can take place, they are also based on traffic conditions, such as travel time, the variability of travel time, ease of driving, and safety. Similarly commercial vehicle operators' decisions are based primarily on cargo origins and destinations and other customer needs, but their decisions regarding routes and times of day to travel are based on traffic conditions. Both groups are most interested in the locations of incidents and travel times.

Table 1 Traffic Performance Measure Needs of Various Potential Users

Data Item	Travelers and Commercial Vehicle Operators	Traffic Information Providers	Transportation System Operators	Planners and Policy Makers	Facility Designers	Researchers
Link-based Information						
Real-time link travel times	X	X	X			
Historical link travel time distributions	X	X	X	X	X	X
Current link densities and flows and historical distributions of link densities and flows		X	X	X	X	X
Raw Traffic Data						X
Incident Information						
Real-time indication of incidents	X	X	X			
Real-time incident particulars	X	X	X			
Historical incident records		X	X	X	X	X

Transportation System Operators

The primary tasks of operators are incident management, ramp metering, lane control, and the provision of traffic information. The decisions they make are how to manage incidents, what metering rates to use, what hours to operate HOV lanes, and what information to provide to travelers and traffic information providers, such as radio stations.

Although incident detection relies heavily on 911 calls, and incident response decisions depend on personnel at the incident site or CCTV when it is available at the incident site, most other decisions made by operators depend on speeds, volumes, and travel times. These include decisions regarding where to position warning-sign trucks in case of an incident and what ramp metering rates to use at various locations at various times of day, as well as what traveler information to provide.

Historical¹ speed, volume, and travel time data is used for scheduling maintenance and construction activities. This data is also used to plan operational strategies, such as what hours to operate HOV lanes and what time-of-day ramp metering rates to use. Historical incident information is used to develop strategies to deal with future incidents. It and the historical traffic data may be used to justify additional investment in resources to manage incidents or recurring congestion or to gather information.

Operators need detailed site- and time-specific information. In California, loop detector data are typically reported at 30-second intervals. This level of detail is useful for locating an incident or the location of the end of a queue. It can be averaged over longer time periods for other uses, such as traveler information or scheduling maintenance and construction.

Capital Investment Planners and Facilities Designers

Historical speeds, volumes, and travel times tell decision-makers at many levels where delay is worst. This can be used to allocate funds between regions and between projects within a region, as well as for the design of projects. In order to locate and design facilities in a way that is most cost-effective in reducing delay, planners must have volume and speed

¹ The term historical is used here to describe any data that is not real-time.

data for other facilities that might be affected by changes in capacity in these locations. Facility designers need information on ramp and mainline volumes in order to provide extra capacity where needed but not where it would not reduce delay.

Each type of decision maker needs different levels of geographical and temporal aggregation. In determining how to allocate funds between regions and within regions, the total level of delay or changes in the total delay would be most useful. Allocations between projects within a region are more likely to be based on the effects of the projects, which would be based not only on the level of delay but also on the cost-effectiveness of various alternative projects in reducing delay. Determining this would require detailed volume and speed data over the entire congested period in the region affected by the project.

Researchers

The same basic data can be used by researchers to develop new guidelines for highway design, to assess the effects of operational strategies such as ramp metering, to develop new ramp metering strategies, and to better understand traffic dynamics. All of this research requires good volume, speed, and density data, but different types of research require different levels of aggregation. Some research requires raw sensor data, such as times when vehicles are sensed or vehicle inductance patterns. This usually requires putting additional components or software in the sensor controller boxes.

Data Characteristics

From the above discussion it is clear that although many types of people use the same measures, the data characteristics they need for a particular measure may be different:

- geographic scope – a facility designer needs data only for the area that will be affected by the facility, whereas a system operator needs data for the entire congested region
- geographic aggregation – a planner needs accident data by specific location in order to determine where safety improvements are most needed, whereas a policy maker needs overall accident data in order to decide what level of resources to assign to safety improvements
- temporal scope – a traveler unfamiliar with the area may want travel time for any time of day, whereas a system operator may need it only for congested periods
- temporal aggregation -- system operators typically use volumes aggregated over intervals of less than a minute, but facility designers can use more aggregated data, the level of aggregation is key in calculating
- currency – real-time measures are needed for applying operational strategies, but historical measures are needed for developing these strategies
- accuracy – traffic adaptive ramp metering requires very accurate measures, but travelers can accept a higher level of error—a travel time estimation error of 2 or 3 minutes would probably be considered acceptable by most travelers
- availability – traffic adaptive ramp metering requires that data be available when the meters are operating, but less reliability is required for planning, which utilizes data over a longer period of time, requiring only that data be available for locations of interest at least some of the time

What these differences imply is the need for archiving data in a large database that can be easily accessed by the various users and for providing software with which various users can select, aggregate, and format the data they need.

Traffic Performance Measures Derived from Data Collected by TMCs

These are the performance measures that can be derived from the type of data collected by TMCs:

- travel time – can be measured directly or estimated from spot speed or volume and occupancy measurements
- speed – spot speeds can be measured at detector locations or inferred from travel times
- reliability – this is the variance in travel time, which can be estimated from the distribution of travel times

- safety – can be measured by the rate and absolute number of various types of accidents by specific location, link, or area, by time of day, week, or year or by weather conditions.

Traffic volume, a key measure for making decisions regarding how to reduce travel time, as well as density, which with volume determines travel time, are generally not included in agencies' lists of performance measures. However, they are included as such in this paper because of their widespread usefulness. Furthermore, volume is a measure of the use of the transportation system, and therefore of its benefit.

How Are TMC-Collected Performance Measures Currently Being Used?

Most TMCs use their real-time data to manage incidents and provide roadside information when needed. Many make incident data and speed data available to travelers, either directly via the Internet or through a traveler information provider. The most common uses of archived data by operations staff appear to be:

- ITS evaluations – archived data are used to compare conditions before-and-after deployment of new operational strategies;
- Work zone management – data are used to determine optimum times or penalty costs for freeway reconstruction and maintenance activities; and
- Performance monitoring – a few agencies use the data to monitor performance on a monthly or annual basis.

The most common uses of archived data by other agencies appear to be:

- Research on ITS and operations – research agencies use archived data to develop and/or evaluate operating strategies (e.g., ramp metering) and algorithms (e.g., incident detection).
- Planning analyses – planning agencies use archived data for numerous activities, such as model calibration, traffic volume factors and characteristics, and congestion management programs.
- Air quality analyses – air quality analysts are beginning to use archived data to develop and calibrate mobile source emissions models.

Few TMCs have routine methods of data access for other users, although some provide data to universities, planners, or consultants upon request. An exception is the Seattle TMC which, as part of the TRAC project, has been archiving detector data and making it available to other users for several years. It currently produces a CD of traffic data every 3 months. California's Freeway Performance Measurement Project is implementing (PeMS), an on-line database of loop detector data that can be downloaded in a variety of formats. It is being developed and managed by the University of California and now contains about a year's data for the Los Angeles detectors that are providing data to the TMC and is beginning to provide data from detectors in the Sacramento area, Orange County and Riverside County. Other TMCs are developing systems whereby another agency, such as a research institute or metropolitan planning agency archives the TMC data for access by other users.

Sensors

The previous section discussed the types of information needed. This section discusses the type of sensors that can provide the information.

Linking Measures to Types of Sensors

Table 2 shows the links between sensors and the type of measures they provide. Two X's indicate that the source provides good information and one X indicates that the source provides some information.

Table 2 Data Sources for Various Data Needs

Data Item	Road-based sensors other than Closed Circuit Television (CCTV)	CCTV	Vehicle-based sensors	Patrol/Traveler Call-in
Link travel times	X	X	XX	
Link densities and flows	XX	X		
Incident detection	X	X	X	XX
Incident details		XX		X

Travel times can be estimated from point speeds at road based sensors, but they can be more accurately estimated by vehicle probes or platoon or vehicle tracking using various features captured by road based sensors and/or video cameras. The latter are currently under development, and may shortly elevate road-based sensors to XX status for collecting travel times. However, with vehicle-based sensors, travel times can be measured directly. Road based sensors are the best means for measuring flows and densities. Reliability is calculated from the distribution of travel times.

Sensor Types and Performance

Primary considerations in selecting detectors are: accuracy of information, reliability, purchase and installation costs, operations and maintenance costs, and useful life span. Less than optimum maintenance may reduce maintenance costs but it will likely also reduce accuracy, reliability and life span. The detectors currently available are described below.

Road-based Sensors

Loop Detectors

These are the most commonly used detectors. They sense when a car enters the pavement over the loop and how long it covers the loop, thus providing a count of vehicles crossing the loop and a measure of the time the loop is occupied from which the vehicle density (vehicles per mile) can be estimated. Loop detectors are sometimes installed in pairs with one a few meters upstream from the other, so that speed can be more accurately estimated. Loop detectors are not always accurate and often are non-functional. The inductance can change with temperature, rain, corrosion, and mechanical deformation. The controller can malfunction, data can be processed in a way that causes errors at low traffic levels, and communications can malfunction or be interrupted. Performance can be enhanced by correcting any shortcomings in the infrastructure surrounding the detectors, updating the controllers used for the loop detectors, updating the communications system for sending loop data to the TMC, and installing “health check software” to identify non-performing and potentially inaccurate loops. Inductive signature detector cards that can automatically adjust for changes in the loop characteristics that cause errors have been developed. These cards can also be used to identify trucks and for matching inductance patterns of vehicle at successive detectors in order to obtain travel times between the detectors [Ritchie and Sun, 1998]. Double loops can be used to measure the lengths of vehicles or groups of vehicles so that they can be matched at successive detector sites. This method is currently being used to estimate travel times on I-80 near Berkeley.

[\[http://www.its.berkeley.edu/projects/freewaydata\]](http://www.its.berkeley.edu/projects/freewaydata)

New loop geometries that provide higher spatial resolution and fewer pavement cuts are being developed. Already developed are micro loops, which are placed in tubes installed a few feet below the roadway. They are less sensitive and have lower resolution than conventional loops but they are less vulnerable to damage and can often be installed and replaced from the side of the road.

RADAR Detectors

These detectors provide counts and density, just like loop detectors. They are commercially available and have been installed in locations in the United States, Asia, and Europe. However, they are not yet widely deployed for freeway traffic monitoring. They are mounted on the side of the road and are relatively easy to install. One sensor can

monitor several lanes of traffic. One supplier has agreed to bundle each detector with a solar electric panel and wireless communication to that they can be installed anywhere, even without electricity or telephone connections.

Video Image Detection Systems

These have been commercially produced for several years and have been used for actuated intersection detection, automated traffic counts, ramp metering, freeway management and automatic incident detection. They can count vehicles and determine presence, like a loop detector. They can also read license plates so that vehicles can be reidentified in order to estimate travel times and origin destination patterns. However, their accuracy can be compromised by occlusion of vehicles, glare, day-night transitions, and reflections from rainy roads.

Comparison of Road Based Sensors

Tables 3 and 4 show the results of a Texas Transportation Institute study of road-based detector performance. [Middleton, Jasek, and Parker, 1999]. These tables are based on data from 1997 and 1998 and so do not reflect the latest performance levels. Also performance can be influenced by local conditions and particular configurations. The costs displayed in these tables include costs of poles and mast arms. The data for loop detectors does not include traffic control and motorist delay costs during installation, which would both be greater than for the competing non-intrusive detector technologies.

Table 3: Quantitative Evaluation of Detectors at Signalized Intersections^a

Technology/Product	Intersection Cost	Detection Accuracy (%)	
		Overhead	Sidefire
Inductive Loops	\$3,278	98	NA
Active Infrared	14,520 ^b	97 ^c	NA
Passive Infrared	8,051	97	NA
Radar	3,590	95	90
Doppler Microwave	6,496	NA	NA
Pulse Ultrasonic	6,350	NA	NA
VIDS	3,370	95	82

^aFour-by-four intersection with single left-turn lane. ^bAssumes four poles with mast arm are needed; no motorist delay or traffic control included. ^cDropped to 77 percent in inclement weather.

Table 4: Quantitative Evaluation of Detectors on Freeways^a

Technology/Product	Cost/Lane ^b	Overhead Accuracy (% of ILD)		Sidefire Accuracy	
		Count	Speed	Count	Speed
Inductive Loops	\$746	98	96	NA	NA
Active Infrared	1,293	97 ^c	90	NA	NA
Passive Infrared	443	97	NA	97	NA
Radar	314	99	98	94	92
Doppler Microwave	659	92	98	NA	NA
Passive Acoustic	486	90	55	NA	NA
Pulse Ultrasonic	644	98	NA	98	NA
VIDS	751	95	87	90	82

^aSix-lane freeway. ^bIncludes cost of pole with mast arm for active IR; includes no motorist delay, but does include traffic control costs for ILDs. ^cDropped to 77 percent accurate in inclement weather.

Closed Circuit Television

Video cameras, especially those with remote pan, tilt, and zoom, are widely deployed for traffic monitoring. Video feeds to television and the internet are favorites with travelers because they give an immediate, comprehensive picture of traffic conditions. They are also useful for planning and managing incident response if the incident is in a camera's field of view. Providing communications between the cameras and the TMC can be expensive. However, systems to provide solar power at the camera site and wireless communications can reduce these costs and the cost of installation.

Vehicle Probes

Toll Tag-equipped Vehicles

This is the simplest and most accurate way to obtain travel times (actually distributions of travel times) between two points. The method that has been most widely deployed is using transponders (generally already used for electronic toll payment), which are read at various locations and matched with readings from other locations. If enough vehicles are equipped with transponders and there are enough readers, this can also provide origin/destination patterns. Incidents can be detected quickly by a sudden and unexpected drop in travel times. Houston is the city where this type of system has been used most extensively. It has been used on a limited basis in New York and New Jersey (the Transmit program), and there are plans to extend the system there.

Vehicles with Cell Phones

The tracking of cell phones promises to provide large amounts of low-cost travel time information, but this technology is still in the early development stage. A test is currently underway in Maryland.

GPS-equipped Vehicles

GPS systems and wireless modems can be installed in vehicles and can be programmed to send a signal to the TMC whenever it passes locations of interest, such as major streets. This system, is also still under development.

What Types of Detectors are Currently Being Used?

Most agencies use some loops, many use double loops. Spacing is often _ mile, but can range up to 2 miles. The area covered in Detroit is 180 miles, but coverage is much less in most areas. A few agencies use radar, microwave, acoustic, or video image detection. Houston and San Antonio use vehicles equipped with transponders, such as used for electronic toll collection, as probes. In Houston the readers are spaced every 2.8 miles on average. All agencies use CCTV.

Communications

Lack of communications between field devices and the TMC is a common cause of a break in the traffic performance measure system circle. One TMC has had 20 miles of double loop detectors at _ mile spacings deployed for 11 years without a connection to the TMC. Communications are an integral part of the performance measure system and they have a large impact on both costs and performance of the system throughout its lifetime. The best communications technologies to use for communicating traffic data will depend on the nature and volume of data, distances between where the data is collected and processed, communication services available in the area, and their cost.

Technologies

There are two categories of communications technologies: wireline and wireless. Wireline technologies include:

- Twisted pair copper
- Coaxial cable
- Fiber optic (multimode and single mode).

Wireless technologies include:

- Microwave

- Cellular (digital and analog)
- Cellular digital packet data (CDPD)
- Spread spectrum
- Digital and trunked radio systems.

Table 5 compares the attributes of the various communications technologies. The table was prepared in 1995, so some characteristics of the media have changed. In particular, there has been a rapid expansion in wireless communication.

Table 5. Comparison of Communication Technologies

	Medium Range Data (5+ miles)	Long Range Data Speed (15+ miles)	Full-Motion Video Compatible	Relative Cost (\$ per bps)	Reliability
Wireline					
Copper twister-pair	1.5 Mbps	1.5 Mbps	No	Low	High
Coaxial cable	100 Mbps	100 Mbps	Yes	Medium	Medium
Multi-mode fiber	500 Mbps	NA	Yes	Low	Very High
Single-mode fiber	40 Gpbs	40 Gpbs	Yes	Very Low	Very High
Wireless					
Digital microwave	155 Mbps	155 Mbps	Yes	Medium	Medium
Digital packet radio	250 Kbps	NA	No	Medium	Medium
Cellular	19.2 Kbps	19.2 Kbps	No	High	Medium
Micro-cellular	NA	NA	Yes	Low	Medium-High

Kbps = thousand bits per second; Mbps = million bits per second; Gbps = billion bits per second

Source: "Benefits of Optical Fiber vs. Copper or Coaxial Transmission Media in ITS Systems", Abernathy, B., Richards, M., and Niebur, D., 1995 ITS America Annual Meeting Proceedings, pp.859-868

Network Topology

There are also choices in the way in which the communication links are connected. These are shown in Figure 2.

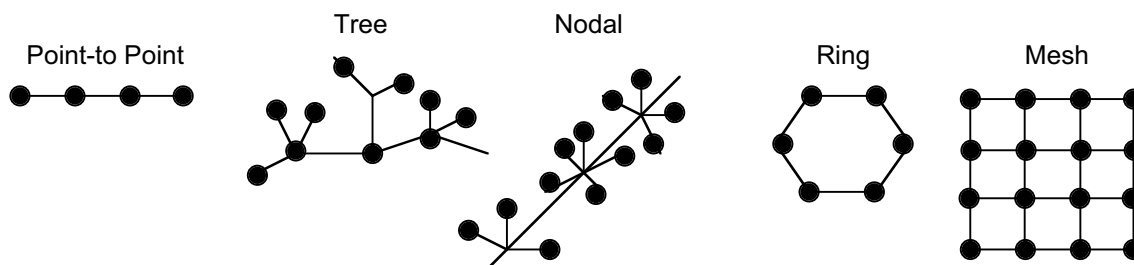


Figure 2. Possible Network Topologies

Source: Federal Highway Administration, Joint Program Office, *Communications for Intelligent Transportation Systems, Successful Practices, Reaching Cost-Effective Solutions through Better Decision-Making Techniques, August 2000*

The choice of communications media and network topology depend on communications needs, system configuration, and cost.

What Types of Communications Do Agencies Currently Use?

Fiber optic cable is a preferred communication medium because of its high capacity and reliability, but it is too expensive for many locations. However, some departments of transportation have been able to obtain low cost fiber optic service as part of the compensation for allowing communications companies to lay fiber optic cable in their rights-of-way. Leased telephone lines have been a common medium, but agencies must make sure that they are providing reliable service. Increasingly, agencies are shifting to radio modems, which are generally less expensive than leased telephone lines. Most agencies use a combination of communications media. For example, Detroit has a fiber optic ring with microwave spokes to hub locations from which copper cables are linked to the field devices.

Data Processing

Some processing takes place at the sensor site, where the raw data is generally converted into traffic data. For example, with a loop detector the magnetic impulse is generally processed into an average flow and occupancy for a short time interval, such as 30 seconds. Or the data may be averaged over only 1 second, or the times between successive impulses may be calculated. The ultimate uses of the data will determine how the data should be processed at the detector site before transmission to the traffic management center. However, the more detailed the data that is transmitted to the traffic management center, the higher the communications cost. Therefore, an agency may choose to transmit data at the level of detail needed for real-time traffic operations and to accumulate samples of more detailed data at the sensor site, to be retrieved manually or transmitted to the center off peak.

Data Quality

Quality has a number of aspects:

- Accuracy -- a high level of accuracy is needed for optimal ramp meter control, but a much lower level of accuracy will suffice for travel time estimates for travelers. At a recent workshop on traffic monitoring Caltrans attempted to obtain consensus on data accuracy requirements. It was clear that the required accuracy depends on the use.
- Reliability -- the data collection system should be maintainable with available resources at the level of reliability needed for it to be useful. The experience in many locations has been that loop detectors require a high level of maintenance. Experience with other detector systems is limited, but experience with video surveillance suggests that any types of detector will require significant maintenance. Maintenance practices clearly affect reliability.
- Absence of Bias – this refers to the extent to which the sensor data reflects the entire facility or network being monitored. Because point detectors sense traffic at only one point, to be truly representative they should be located wherever the traffic conditions would differ from adjacent locations, for example on an on-ramp and between each pair of ramps. In a probe vehicle system utilizing toll tags, spacing of toll tag readers determines the level of geographic aggregation, and the number of probe vehicles needed to adequately represent conditions between each pair of readers depends on the variance in vehicle speed and the rate at which speed is changing. Research has found that a relatively small number is sufficient. However, the further the distance between readers, the smaller the proportion of vehicles that will travel the full distance between them.
- Validity of estimation methods – in some systems missing data is replaced by estimated data; users who are unaware of this practice can draw erroneous conclusions from the data. Data collection, processing, and error handling methods should be documented and readily available to all data users.

Table 6 shows the accuracy and reliability requirements for various uses of the different types of data.

How Do Agencies Currently Control Quality?

One way to improve data quality and reliability is to perform continual error checks on the data to determine if it is reasonable. This makes it possible to detect problems with the data and promptly correct them. Most agencies use some type of basic error checking that identifies physically impossible or implausible data values, such as average 5-minute speeds greater than 80 mph or total 5-minute by lane

Table 6. Data Accuracy, Reliability, and Currency Requirements for Various Uses

Data Item	Information for Travelers and Commercial Vehicle Operators	Incident Detection	Adaptive Ramp Metering or Signal Control	Planning and Policy-Making	Facility Design	Research
Link-based Information						
Real-time link travel times	A=m R=h	A=h R=v	A=v R=v			
Historical link travel time distributions	A=m R=m	A=h R=h	A=v R=v	A=m R=m	A=h R=m	A=h R=m
Current and historical link densities and flows		A=h R=v	A=v R=v	A=m R=m	A=h R=m	A=h R=m
Raw Traffic Data						A=v R=m
Incident Information						
Real-time indication of incidents	A=h R=h	A=v R=v	A=v R=v			
Real-time incident particulars	A=h R=h	A=v R=v	A=v R=v			
Historical incident records		A=v R=v	A=v R=v	A=m R=m	A=v R=m	A=v R=m

A=accuracy R=reliability

v=very high h=high m=medium

vehicle counts greater than 250. This error checking is performed at either the detector controller level or the central database/archiving level. Most agencies will set data errors to special codes (e.g., “-1” or “255”), but few provide information or codes as to why the data was considered erroneous and dropped.

A few agencies use more sophisticated error checking, such as checking for implausible combinations of data values, such as occupancy less than 5 percent but speed less than 20 mph. Researchers at several locations have developed more sophisticated error checking procedures, but these have not been implemented because a) they require more data than is typically available in real-time or through the controller or b) the error checking algorithms are too complex for most operating agencies to implement.

Some agencies prepare reports on which devices are not reporting. Some do maintenance on a weekly cycle, some on a daily basis. Generally those agencies that find loop detectors to perform well are those that investigate any lack of signal or apparent error as soon as it occurs and then make prompt repairs.

Data Format

Earlier, the differing data characteristics required by users were discussed. Ideally, the most detailed data received from the sensors would be stored in a large database and software would be provided to allow users to specify the temporal and geographical scope and level of aggregation and the data layout needed for their use.

The software could also provide useful graphical representations. Thus the same database could serve many users and uses.

Data Archiving

The huge reductions in the cost and space required for storing data have made it possible to archive orders of magnitude more data at a higher level of detail than would have been possible even only a few years ago. However, managing and retrieving data still requires significant resources unless the storage and retrieval process can be fairly automated.

Although the archived traffic is useful to planners, facility designers, and researchers, meeting their data needs is generally not considered a responsibility of the people at the TMC who collect the data. Organizations do well those things that are closely related to their core mission. Few organizations have the staff to provide a high level of service to other organizational units that are not involved in carrying out this mission. The mission of the TMC is to manage traffic, particularly incidents. It is not generally to plan, to design facilities, or to conduct research. This presents an organizational problem that must be overcome if full use is to be made of the traffic data. One way is to transfer the TMC data to another agency or organizational units whose responsibility is to archive the information and make it available to all potential users in a useful format.

How Is Traffic Data Currently Archived, Managed and Disseminated?

A USDOT study found that over 80% of agencies collecting traffic volume data archive that data and over 60% collecting speed data archive that data (see Table 7). In many locations, the de facto group for maintaining a data archive has been the operations workgroup/agency, since they are simply saving their own data. However, in some of these locations, the operations workgroup only maintains “recent” data until it can be transferred to some other group/agency for ultimate long-term storage and/or management. Or in some cases, the operations workgroup archives data in a convenient storage format (compressed text) but does not make the data accessible or easy to use or analyze.

Table 7. Summary of Data Archiving Practices as Reported to U.S. DOT, 1999

Type of System	Type of data	% of agencies archiving
Freeway Management	Vehicle traffic volumes	87% (59 of 68)
	Vehicle classification	76% (37 of 49)
	Traffic incidents (time sequence of events, location, cause, number of lanes blocked, etc)	67% (35 of 52)
	Vehicle speeds	66% (31 of 47)
	Current and scheduled work zones (location, number of lanes closed, scheduled duration, etc)	53% (34 of 64)
Arterial Street Management	Vehicle traffic volumes	83% (134 of 162)
	Turning movements	83% (94 of 113)
	Traffic incidents	83% (34 of 41)
	Phasing and cycle lengths	80% (91 of 114)
	Vehicle speeds	79% (80 of 101)
	Traffic signal preemption info	75% (46 of 61)
	Current work zones	72% (52 of 72)
	Scheduled work zones	67% (43 of 64)

Source: U.S. DOT ITS Deployment Tracking Database, 1999 Results.

In a few areas, the MPO or another agency has taken the lead in maintaining and managing a data archive for themselves and other agencies in the region. These data archive managers then consider themselves responsible for providing these basic data archive functions:

- Ensuring that the data is easily accessible, either through the Internet or on CDs by request.
- Providing information and documentation on the data.
- Performing quality control
- Providing software applications that help to analyze the data, or providing data formats that can be easily analyzed by other's software.

For example, the operations group in WsDOT has developed analysis software and publishes an archived data CD every 3 months. In California, Caltrans has taken the lead in developing PeMS, which makes archived data and various data summaries available through a web site. In Virginia, the Virginia Transportation Research Council has been charged with maintaining statewide ITS data archives, and handle the long-term management and distribution of this data. With a few exceptions, agencies that are using archived operations data for significant analyses are storing that data in a relational database (e.g., Oracle, Sybase, Informix, SAS). Access to the data in a relational database is then provided by using either special programming languages (e.g., SQL, or structured query language) or through a graphical user interface, such as a web browser or database query window. For example, several universities have developed data archives in which the relational database is queried using simple menus and selections in a web browser window. In most cases, the use of a relational database also requires a database administrator who manages day-to-day operations of the database and develops user applications.

Several agencies are archiving their operations data in file-based systems (e.g., either ASCII or binary). In locations like Seattle, they have developed custom software that can be used to manipulate the numerous data files associated with their archive. In other locations, compressed text files have simply been used as either a long-term storage format or as an intermediate format in which to distribute the data to other agencies. For example, agencies in Austin, San Antonio and Phoenix archive operations data into a compressed ASCII-text file for later use by other agencies.

The storage period for data archives varies depending upon data uses, but most agencies use some type of data cataloging process whereby the most recent data is kept "on-line" (e.g., a computer hard disk drive) and older data is kept "near-line" or "off-line" (e.g., CD or magnetic tape cartridges). Nearly all agencies do keep a permanent archive, with very few "erasing" or disposing of old data. Several agencies are planning to have the most recent 12 months on-line and available, whereas owners of smaller archives maintain several years on-line. Additionally, some agencies keep summaries (such as hourly averages) of older data on-line while permanently archiving detailed data (such as 1 or 5-minute data).

Conclusions and Recommendations

Better Utilization of Archived Data Will Take Time and Experimentation

Archived data are a rich resource for improving all types of transportation decisions, but are rarely fully utilized. Typically, the regions in which data archiving and performance monitoring are most prevalent and widespread are those in which local/state agencies have been archiving and analyzing data for at least 5 or 10 years. For example, the archived data in Seattle has been widely distributed for at least the past 5 years and has become somewhat institutionalized. This finding suggests that agencies in other regions may be likely to adopt archived data for performance monitoring once they 1) learn more about how much and what data is available from this "new" data source (ITS); 2) have the quality and use of that data demonstrated through practical applications; and 3) experiment with archived data to ensure that it meets their needs. Changing the way that institutions make decisions, particularly costly infrastructure investment decisions, is slow and evolutionary. However, it is hoped that this report may help TMCs build upon the experience of other TMCs, thus reducing the time needed to fully implement a performance measurement system based on archived traffic data.

Archived Traffic Data Should be Used to Improve Traffic Management Center Performance

This review of TMCs found that many view their mission solely as “crisis management.” Some see little connection between historical archived data and the crises they manage on a day-to-day basis. However, numerous other “operations-based” companies inside and outside of transportation make extensive use of “archived” operations data because their profits depend upon their ability to exploit that data to develop ways to operate more efficiently and effectively. For example, trucking and package delivery companies keep extensive records of package locations and times, and then analyze these shipping times to find locations of inefficiency. Most automated manufacturing facilities will track performance of certain machines or equipment to ensure maximum efficiency. Similarly, TMCs should analyze performance data to determine the optimum way to manage crises and to develop other means of operating the transportation system at its maximum efficiency. Because most TMCs are already short of resources, more resources will be needed to meet this true operations mission.

The Key to Effective Data Archiving Is Assignment of Responsibility and Adequate Funding

Our review found numerous institutional models used in maintaining ITS data archives. One thing was clear: there are numerous uses of the data beyond any single workgroup or agency. To date, archived data are being used by operators, planners, researchers, air quality analysts, transit providers, consultants, media, and others. In most cases, however, the data were being maintained by operations personnel simply because they own the equipment that collected the data. The maintenance of data archives by TMCs could be seen as burdensome in some locations, particularly if the operations agency did not use the data. Essentially, what is needed is an “transportation information services” unit that can collect and disseminate this type of data. In some areas, metropolitan planning organizations are preparing to fill this role (e.g., Dallas-Ft. Worth, Cincinnati, Detroit). In other areas, the state or local DOT has taken on this responsibility (e.g., California, Seattle, Houston, Atlanta, Phoenix). The determination of which agency maintains data archives has strongly depended on existing institutional structures and relationships. Although there are many possible models, and it is not clear whether one model is better than the others, it is clear that an adequately funded organizational unit responsible for archiving and disseminating the data is essential to obtaining the full benefit from the traffic data that TMCs collect.

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Appendix A Case Studies

AGENCIES AND PEOPLE INTERVIEWED

DALLAS, TEXAS

- Ms. Terry Sams, TxDOT (214) 320-6231 tsams@mailgw.dot.state.tx.us
- Mr. Andy Oberlander, TxDOT

FORT WORTH, TEXAS

- Mr. Wallace Ewell, TxDOT (817) 370-6788 wewell@dot.state.tx.us
- Ms. Gina Flores, TxDOT (817) 370-6820 rflores@dot.state.tx.us

HOUSTON, TEXAS

- Ms. Sally Wegmann, TxDOT (713) 802-5171 swegman@mailgw.dot.state.tx.us

SAN ANTONIO, TEXAS

- Mr. Pat Irwin, TxDOT (210)731-5249 pirwin@mailgw.dot.state.tx.us

ATLANTA, GEORGIA

- Mr. Mark Demidovich, Navigator, Georgia DOT (404) 635-8009 mark.demidovich@dot.state.ga.us
- Dr. John Leonard, Georgia Tech Research Institute (404) 894-2360 john.leonard@ce.gatech.edu

DETROIT, MICHIGAN

- Mr. Arvyd Satritis, Michigan DOT (312) 256-9800 satritis@mdot.state.mi.us

HAMPTON ROADS, VIRGINIA

- Mr. Stephany Hanshaw, VDOT Smart Traffic Center (757) 424-9907 hanshaw_sd@vdot.state.va.us
- Mr. Rod Turochy, Virginia Transportation Research Council (804) 293-1918 turochy@vdot.state.va.us

MONTGOMERY COUNTY, MARYLAND

- Mr. Bruce Magnum, Montgomery County DOT (240) 777-8778 bmangum@dpwt.com
- Mr. Richard Roisman and (301) 495-4547 rroisman@mncppc.state.md.us
- Mr. Don Ostrander, Maryland-National Capital Park and Planning Commission (M-NCPPC) (301) 495-2184 pstramder@mncppc.state.md.us

PHOENIX, ARIZONA

- Mr. Manny Agah, Arizona DOT (602) 712-7640 magah@dot.state.az.us
- Mr. David Wolfson, Maricopa County DOT (602) 506-6950 DaveWolfson@mail.maricopa.gov

ORANGE COUNTY, CALIFORNIA

- Mr. Mahesh Bhatt, Irvine TMC, Caltrans (949) 724-2400 mahesh_bhatt@dot.ca.gov

SAN DIEGO, CALIFORNIA

- Mr. Tarbell Martin, San Diego TMC, Caltrans (858) 467-3204 tarbell_martin@dot.ca.gov

ANAHEIM, CALIFORNIA

- Mr. John Thai, City of Anaheim (949) 765-5202 jthai@anaheim.net

MINNEAPOLIS, MINNESOTA

- Mr. Nick Thompson, MnDOT (612) 341-7269 nick.thompson@dot.state.mn.us

DALLAS, TEXAS

Contact Names and Agencies:

- Ms. Terry Sams and Mr. Andy Oberlander, TxDOT
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (closed circuit TV)
- Traffic control & management (changeable message signs)
- Traveler information (pre-trip is provided via web site and media outlets, en-route via roadside message signs)
- DalTrans does not track system performance; however, they have recently begun to deploy freeway traffic monitoring capability (video detection).

What data is currently collected (and how) to support these functions?

- in the near future, point data (volume, occupancy, speed) from video
- video from CCTV
- incident information
- current & scheduled work zones

What data is currently archived?

- incident information
- current & scheduled work zones

Who uses archived ITS data and for what?

- At this point, significant data are not archived.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- Not applicable.

Are performance measures used for decision support? If so, for what decisions and how?

- Not applicable.

Any question/concerns/comments are noted here.

FORT WORTH, TEXAS

Contact Names and Agencies:

- Mr. Wallace Ewell, Ms. Gina Flores, TxDOT
- Mr. Dan Rocha, North Central Texas Council of Governments
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, closed circuit TV)
- Traffic control & management (ramp meters, changeable message signs, lane control signals)
- Traveler information (pre-trip is provided via web site and media outlets, en-route via roadside message signs)
- TxDOT-Ft. Worth has developed procedures to track system performance that rely on archived data; however, they have not implemented these procedures on an ongoing basis yet.

What additional functions would you like to provide or enhance?

- Has plans to operate a data warehouse at TransVISION, as well as share data with NCTCOG's central information clearinghouse.

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed, percent trucks) from double loops and radar detectors, typically every _-mile
- current coverage is about 39 miles
- video from CCTV
- metering rates and ramp queues
- incident information
- current & scheduled work zones

What data is currently archived?

- video snapshots associated with incidents
- incident information
- current & scheduled work zones

Who uses archived ITS data and for what?

- At this point, archived data used mostly by state universities.
- Data used for research purposes, ITS evaluation, and traffic planning purposes.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- TransVISION has plans to operate a local data warehouse for their purposes, as well as share data to other centers, such as NCTCOG's planned information clearinghouse. Particulars about the TransVISION and NCTCOG data archives are being planned at this time.

Are performance measures used for decision support? If so, for what decisions and how?

- Archived data has been used to evaluate ramp metering, as well as being used in other research evaluation projects.

Any question/concerns/comments are noted here.

HOUSTON, TEXAS

Contact Names and Agencies:

- Ms. Sally Wegmann, TxDOT
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector and probe vehicle surveillance, closed circuit TV)
- Traffic control & management (ramp meters, changeable message signs, lane control signals, HOV lanes)
- Traveler information (pre-trip is provided via web site and media outlets, en-route via roadside message signs)
- TxDOT-Houston tracks system performance on an annual basis using probe vehicle data from the AVI traffic monitoring system. The TranStar web site also contains charts that show current travel times versus historical performance.

What additional functions would you like to provide or enhance?

- Has plans to operate the TranStar data warehouse, which will contain selected data items generated by TranStar and be shared with partnering agencies.

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed, percent trucks) from double loops and some VIDS, typically every 1/2-mile, about 30 miles of coverage in 1999
- probe vehicle travel times from the AVI traffic monitoring system, average AVI tag reader spacing is 2.8 miles
- video from CCTV
- metering rates and ramp queues
- incident information
- current & scheduled work zones

What data is currently archived?

- anonymous vehicle travel times
- volume, occupancy and speed from loops and VIDS since mid-2000 by TTI

Who uses archived ITS data and for what?

- At this point, archived data used mostly by state universities.
- Data used for research purposes, ITS evaluation, and traffic planning purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- TTI-Houston office currently maintains travel time data from the AVI traffic monitoring system. The TTI-Houston office has also been archiving loop detector data from the TranStar database since mid-2000 under agreements with TxDOT.
- Planning is underway for the TranStar data warehouse, which will eventually archive numerous data elements being generated or collected at TranStar. The data warehouse will be managed through a relational database, with access through internal networks or the Internet.

Are performance measures used for decision support? If so, for what decisions and how?

- Archived data has been used to evaluate ramp metering as well as overall system performance at TranStar.
- For the past several years, TranStar has published an annual summary of benefits that draws upon data collected by the AVI traffic monitoring system. This document is distributed to all of the TranStar partner agencies.

Any question/concerns/comments are noted here.

SAN ANTONIO, TEXAS

Contact Names and Agencies:

- Mr. Pat Irwin, TransGuide, TxDOT
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, closed circuit TV)
- Traffic control & management (changeable message signs, lane control signals)
- Traveler information (pre-trip via web site or low-powered TV, en-route via roadside message signs)
- Highway-rail intersection monitoring
- TransGuide does not track system performance. The MPO is responsible for developing a congestion management system, and TxDOT participates through their planning group.

What additional functions would you like to provide or enhance?

- Operational strategies? Capital planning? Work zone management?
- VIA Metropolitan Transit has plans to use their automatic vehicle location data to track performance and contribute to the MPO's congestion management system.

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed) from double loops, video detectors typically every _-mile
- link travel times from AVI traffic monitoring system
- current coverage is about 53 miles
- video from CCTV
- incident information
- current & scheduled work zones

What data is currently archived?

- traffic volume, occupancy & speed
- probe vehicle travel time
- vehicle classification
- ramp queues (??)
- incidents
- current & scheduled work zones
- road & weather conditions

Who uses archived ITS data and for what?

- Archived data used mostly by agencies other than TransGuide, such as state universities and other research groups.
- Data used primarily for research purposes, ITS evaluation, and traffic planning purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- TransGuide currently maintains a publicly-accessible FTP site that has the most recent month of data files in ASCII-text format. Various users download files as needed and develop/maintain their own databases locally.
- Data are stored as 20-second lane records from freeway mainlanes and entrance/exit ramps.
- Basic quality control is presumably done at the controller level, but is unknown.

Are performance measures used for decision support? If so, for what decisions and how?

- Does TransGuide uses archived data and any performance measures to help make decisions about capital projects, maintenance, etc?

Any question/concerns/comments are noted here.

- TransGuide archives most of their data to ASCII-text files for use by other agencies, but they do not see themselves as regular users of data archives and thus have not further developed their data archive beyond what already exists.

ATLANTA, GEORGIA

Contact Names and Agencies:

- Mr. Mark Demidovich, Navigator, Georgia DOT
- Dr. John Leonard, Georgia Tech Research Institute
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, CCTV, service patrol)
- Traffic control & management (changeable message signs, lane control signals)
- Traveler information (pre-trip via web site and media, en-route via roadside message signs)
- Atlanta's Navigator does archive detector data but at this point does not systematically monitor performance.

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed) from VIDs, typically every 1/3-mile
- current coverage is about 40 miles
- video from CCTV
- incident information
- current & scheduled work zones

What data is currently archived?

- traffic volume, occupancy & speed

Who uses archived ITS data and for what?

- To date, archived data used mostly by university researchers (Georgia Tech).
- Data used primarily for research on operational strategies, ITS evaluation, and traffic monitoring and planning purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- GDOT maintains archived data in ASCII-text files at the 15-minute level.
- GDOT also provides this data on CD upon request.
- Researchers at Georgia Tech also maintain the archived data in a relational database, and use the data for a variety of research projects.

Are performance measures used for decision support? If so, for what decisions and how?

- Performance measures used mostly at the MPO level (Georgia Regional Transportation Authority).

Any notable items or questions/concerns/comments are noted here.

DETROIT, MICHIGAN

Contact Names and Agencies:

- Mr. Arvyd Satritis, Michigan DOT
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, CCTV, service patrol)
- Traffic control & management (ramp meters, changeable message signs, lane control signals)
- Traveler information (pre-trip via web site and media, en-route via roadside message signs)
- Track performance???

What additional functions would you like to provide or enhance?

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed) from double loop detectors, typically every 2 miles
- current coverage is about 180 miles
- video from CCTV
- incident information
- current & scheduled work zones

What data is currently archived?

- traffic volume, occupancy & speed

Who uses archived ITS data and for what?

- Archived data shared with Detroit MPO for traffic planning and analysis purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- Michigan DOT collects data in 20-second intervals from the detectors, then aggregates to 1-minute once at the center. MDOT maintains the most recent data “on-line” for a short period (about one week), then permanently archives to magnetic tape cartridges.

Are performance measures used for decision support? If so, for what decisions and how?

- Most performance measurement activity in Detroit is focused at the MPO.

Any notable items or questions/concerns/comments are noted here.

HAMPTON ROADS, VIRGINIA

Contact Names and Agencies:

- Mr. Stephany Hanshaw, VDOT Smart Traffic Center
- Mr. Rod Turochy, Virginia Transportation Research Council
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, closed circuit TV)
- Traffic control & management (changeable message signs, lane control signals)
- Traveler information (pre-trip via web site and media, en-route via roadside message signs)
- Hampton Roads Smart Traffic Center (STC) does not currently track system performance.

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed) from double loops, microwave radar and acoustic detectors typically every -mile
- current coverage is about 47 miles
- video from CCTV
- incident information
- current & scheduled work zones
- road & weather conditions

What data is currently archived?

- traffic volume, occupancy & speed
- incident information

Who uses archived ITS data and for what?

- Archived data used mostly by Virginia Transportation Research Council (VTRC).
- Data used primarily for research on operational strategies, ITS evaluation, and traffic monitoring and planning purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- VTRC operates and maintains the ITS data archives for VDOT, as per their most recent data sharing policy. VTRC polls the STC real-time database in Hampton Roads every two minutes to retrieve updated traffic data.
- VTRC stores 2-minute detector and station data, as well as any incident data, in an Oracle relational database.
- VTRC does basic quality control on the data using min/max value thresholds for volume and occupancy, as well as looking at average effective vehicle lengths.

Are performance measures used for decision support? If so, for what decisions and how?

- Hampton Roads STC uses some performance measures for decision-making, but no measures based upon the archived data. The MPO uses performance measures in several of its programs.

Any notable items or questions/concerns/comments are noted here.

- VTRC, as the research arm of VDOT, has been designated to maintain the ITS data archives. Although research agencies are the primary users in many areas, Virginia is the only state where a research agency has been officially charged with managing and maintaining the archived data.

MONTGOMERY COUNTY, MARYLAND

Contact Names and Agencies:

- Mr. Bruce Magnum, Montgomery County DOT
- Mr. Richard Roisman and Mr. Don Ostrander, Maryland-National Capital Park and Planning Commission (M-NCPPC)
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (loop detectors, closed circuit TV, fixed-wing aircraft)
- Arterial traffic control & management (closed-loop signal system, emergency vehicle preemption, changeable lane assignment signs, transit)
- Traveler information (pre-trip via web site, cable TV, kiosk and media; en-route via highway advisory radio, telephone, and roadside message signs)
- Operating center does not track performance except for periodic evaluation or benefit studies.

What data is currently collected (and how) to support these functions?

- sampling (at mid-block) and presence (at intersections) loop detectors
- current coverage is about 200 intersections
- video from 80 CCTV cameras
- incident information and special events
- current & scheduled work zones

What data is currently archived?

- Traffic volumes are transferred to and archived by M-NCPPC
- Probe vehicles
- Incidents
- Current & scheduled work zones

Who uses archived ITS data and for what?

- Archived data used primarily by (M-NCPPC) for traffic planning and analysis purposes, such as network volume maps, model calibration, alternative network testing, time series analysis, and quick “traffic snapshots.”

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- Montgomery County DOT stores 5-minute volumes in an Informix database on a short term-basis.
- M-NCPPC uses Internet protocols (TCP/IP) and a custom software product to query the DOT database in the early morning and retrieve the most recent 24 hours of 5-minute volume data (at this time, a 7 MB file transfer). Once the data has been retrieved, M-NCPPC loads the data into an Oracle server, does error checking, then computes peak hour intersection volumes and other volume quantities used in planning applications.

Are performance measures used for decision support? If so, for what decisions and how?

- Some performance measures are used, but these measures are not derived from any archived data.

Any notable items or questions/concerns/comments are noted here.

- The coordination and resource sharing of an operations and planning agency is notable. This partnership occurred largely because an operations manager transferred to the planning agency—this person provided the institutional connection to make the data sharing work.

PHOENIX, ARIZONA

Contact Names and Agencies:

- Mr. Manny Agah, Arizona DOT
- Mr. David Wolfson, Maricopa County DOT
- US DOT 1999 ITS Deployment Tracking Database, <http://www.itsdeployment.its.dot.gov/>

What functions does your operations center currently provide?

- Incident detection & management (detector surveillance, closed circuit TV, incident response team)
- Traffic control & management (changeable message signs, HOV lanes)
- Traveler information (pre-trip via web site, cable TV, kiosks, pagers, e-mail, and media; en-route via telephone, pagers, roadside message signs)

What data is currently collected (and how) to support these functions?

- point data (volume, occupancy, speed, vehicle classification) from double loops and passive acoustic detectors, acoustic detectors typically every 1/3-mile
- current coverage is about 75 miles
- video from CCTV
- incident information
- current & scheduled work zones

What data is currently archived?

- traffic volume, occupancy, speed, & vehicle classification

Who uses archived ITS data and for what?

- Archived data used mostly by ???.
- Data used primarily for research on operational strategies, ITS evaluation, and traffic monitoring and planning purposes.
- Data also being used in FHWA Mobility Monitoring Study being conducted by TTI/Cambridge Systematics.

Describe particulars about archived data (e.g., who maintains/operates, quality control, storage life).

- ADOT maintains the original 20-second data as collected from the detectors. They store recent data on-line in compressed text formats, and keep old data on CDs. They have developed software to provide archived data upon request in a number of different aggregation levels and formats.
- The Maricopa County DOT is planning to operate a regional archived data server (RADS), which will include ADOT's freeway data as well as other data sources. This regional data archive may not be operational until 2002.

Are performance measures used for decision support? If so, for what decisions and how?

- There are plans for performance measures at the MPO, but no current plans for performance measures at the operations level.

Any notable items or questions/concerns/comments are noted here.

- The Arizona DOT does have a history of archiving detector data, with data on CDs extending back to 1995.

Orange County, California

Contact Name and Agency:

- Mr. Mahesh Bhatt, Caltrans, Irvine TMC

How do you use the data you collect?

Traveler information

Incident information goes to the media, CHP also broadcasts on the net, can post it on 49 CMS at major decision points on major streets and highways (will have more in the future) ,Anaheim also has signs, uses 6 portable signs on trucks that follow the back of the queue.

Congestion information: OCTA uses data base to obtain congestion information, which it then disseminates.

Real time operations

Ramp metering: they do not have centralized control of ramp meters. If there is a problem that lasts more than 4 hours or a planned event (such as at the Anaheim convention center) they go out and change the meters and local intersection signals manually.

The CHP manages the 32 FSP tow trucks out of the TMC. Tow trucks have assigned beats determined by the CHP. The TMC uses the data for planning link closures for maintenance or special events.

Developing operational strategies

The system support staff (as opposed to the operations staff) analyzes the data to determine what the ramp metering rates should be.

The system support group uses the data for a lane control database.

The data is also used for evaluation and analysis of major incidents.

System monitoring

They do periodic manual studies of occupancy on HOV lanes. All HOV lanes operate 24 hours a day.

Capital planning

The planning department uses the data, which is archived for 1 year, to determine what alternatives to consider in planning capital improvements. They use it in doing their B/C analyses of alternatives.

TMC staff training

Their data is used in the simulator at the training centers at Cal Poly at San Luis Obispo

Research

UC Irvine has a direct fiber optic link to the TMC, which provides loop and video data.

Planned new uses

Operations group plans to use it for accident analysis

Data sources

Video –now have 50 cameras, ultimately want 180 to 200 so that they can see the entire freeway network

Loops—now have 560 stations, single loops every _ to 1 mile

Ramp meters also do counts

Communication

Information now communicated by phone lines. Field devices will be connected to the new center by fiber optics.

Data processing

The system support group prepares reports regarding which devices are down and which need repair. Every Monday morning they check the loops and make a maintenance plan for the week.

The receive both 15 second and 30-second data. Most people use the latter.

Data storage

Data is stored on the server for a year and is backed-up on tape. The data is handled by the system support group.

Data access

Data is public record. It is available to anyone at no charge. The only users now are cities, Anaheim and Irvine, and universities, CalPoly and UCI. The cities like the data. It is shared electronically.

Emerging technologies

Working with the So Cal Priority Corridor on tying everything together.

Problems encountered

No lessons learned. Open architecture has worked well. No data problems.

What they want to know

Information about the performance and cost of new types of sensors. Benefit of TMC activities.

San Diego

Contact Name and Agency:

- Mr. Tarbell Martin, Caltrans, San Diego TMC

How do you use the data you collect?

Traveler information

Caltrans volume and speed estimates from loops, as well as information on confirmed incidents are sent via the internet to the media and traffic reporting services for dissemination to travelers.

Real time operations

The TMC's principal activity is incident management. They have a close working relationship with the CHP which is also located in the TMC. Although they have a system that tells them when speeds drop precipitously, 911 calls are the principal source of incident detection, but locations given by callers tend to be quite inaccurate. Therefore, they rely on a CHP officer or freeway service patrol operator to verify the incident and provide information regarding incident particulars. This data is used to determine what type of equipment to send to the scene, where to locate mobile changeable message signs and what information to provide on changeable message signs and through the media. The TMC operates a limited number of CCTV cameras, but they are expensive to install and unreliable. There are 270-300 ramps that have meters. There are loop detectors on these ramps and adjacent mainlines.

Developing operational strategies

Sometimes these decisions are supported by hard data, sometimes they are based on experience. Accident and incident information is kept in the CHP log, but is not plotted on a map. The TASAS data base is good but does not include information on accidents that did not involve injuries.

Capital planning

The TMC keeps 30-second data on speed and volumes and peak 3 _ hour plots on a server for 13 _ months. During this time planners can download the data from the server.

Construction and maintenance scheduling and monitoring

Traffic data is used for determining what time of day to do construction and maintenance. It is also used to verify that contractors adhere to the schedule.

Research

Several research organizations use the data for various studies, including federal projects.

Data sources

Loops—There are loops on the 270+ on-ramps that are metered and the adjacent mainlines. There are also 20-30 miles of double loops spaced every half- mile that have been in the road for 11 years but that are not yet connected to controllers.

Other sensors—They have tried sonic and infrared sensors but did not find them as economical as loop detectors. There is a group of electrical technicians who keep the loop detectors functioning. If communications from any of the loops is reported, they investigate as soon as possible, usually the same day.

Communications

Loop data is sent to the TMC via leased telephone lines, which have high priority in case of an emergency. When there is an freeway incident that lasts for an hour or more, the cell sites often become overloaded by calls from people stuck in the resulting traffic.

Data processing

The people who manage the servers and do the analytical work are located in the TMC building and are highly valued.

Data storage

Loop data is stored on the server for 13 _ months, and then destroyed.

Emerging technologies—Plans for the future

The TMC has proposed an ambitious Incident Management & Non-Recurrent Congestion Relief program that includes increasing the efficiency of incident scene management, providing better communications to the media and traveler, deploying more resources to manage queues, and enhancing emergency management team coordination.

The purpose is to clear accidents sooner and reduce secondary accidents.

They want to connect the double loops that have been installed but not connected to the TMC. They want to install more loop detectors on ramps and to have loop detectors at _ mile spacing in all congested areas so that they can be used to verify incident locations. They want to have more complete information so that they can better assess the effects of changes in operations and justify programs such as the incident management and congestion relief program noted above.

Public information program to train the public in the use of 911, to improve the accuracy of information they report.

What they want to know

They want to know how to assess the benefits of changes in traffic management strategies and justify investments in information gathering and incident management.

Anaheim, California

Contact Name and Agency:

John Thai, Manager of Traffic Management Center, City of Anaheim

How do you use the data you collect?

Traveler information

They do not provide information directly to travelers. They send their loop data to a Travel Tip work station where it is processed and combined with other information for dissemination from Travel Tip servers to the Internet, a highway advisory telephone system, and kiosks.

Real-time operations

Their primary job is event management for Disneyland, the Arrowhead Pond, the Convention Center and the Edison International Fields. They use the information to change signal timing and messages on 10 large changeable message signs that provide route and parking information. They operate from 7AM to 7PM and additional hours as needed for special events.

Developing operational strategies

The traffic data is archived only as needed for developing basic time of day signal plans and making and evaluating plans handling special events.

No Plans for Using the Data in Other Ways

Data sources

Loop detectors

Signals – all signals are actuated and provide flow

Video –now have 50 cameras

Video image processing –these are getting more reliable but still are not quite as accurate as loop detectors

Communication

There is fiber between the TMC and 8 hubs. Copper, twisted pair connects the hubs to the 285 signals and the CMSs.

Error Checking

This is not necessary because if equipment is not functioning properly, signals do not operate properly and travelers let the TMC know.

Minneapolis, Minnesota

Contact Name and Agency:

- Mr. Nick Thompson, Operations Manager, Metro District Transportation Management Center

How do you use the data you collect?

Traveler information

They have a map on the web that shows congestion levels every minute and icons indicating various types of incidents. They also post the data on a server that can be accessed by organizations providing traffic information. It is used to provide traffic reports on the radio and television, SmarTraveler's telephone traveler information and other traffic web sites.

Real time operations

Detector data is used for incident detection and for setting metering rates at 430 ramp meters in the region. The ramps were originally activated by congestion. Now they also use historic detector data to set fixed rates by time of day. They also use real time information to advise travelers with changeable message signs.

Developing operational strategies

Yes.

Capital planning

It is used for simulations for evaluating capital projects. It is also used by the MPO and the DOT.

Construction and maintenance scheduling and monitoring:

It is frequently used for scheduling lane closures.

Data sources

Loop detectors are located about every _ mile on 75% of the metropolitan area's 250 miles of freeways. There are about 4000 detectors. They check for errors in the detectors using software that was developed in-house. Approximately 96% are functioning at any one time. They also have about 230 closed circuit televisions.

Communications

Communication in most locations is via fiber optics. Communications between the loops and cabinets is sometime via twisted pair. MnDot owns and maintains the communication system, which they also designed.

Data processing

Data storage

Traffic data has been archived since 1984. It is now stored on the server for 1 year and then transferred to CDs. Anyone in MnDOT can access the data anytime. They also have a data sharing agreement with the University of Minnesota and the MPO. Consultants can access the data upon request.

Emerging technologies—Plans for the future

The traffic management center is moving to a new center that will be jointly used by maintenance personnel, the state patrol, and the signals group.

They plan to install a new computer system that will provide the potential to do more with the data, such as producing more performance measures. They have 5 in-house programmers.

They plan to replace the 170 controllers, hopefully skipping to a new technology.

Appendix B. Improving the Traffic Performance Monitoring System

There are three primary considerations in improving an existing system:

- 1) the data needed
- 2) the existing system:
 - a) the extent to which it provides the needed data
 - b) the feasibility and cost of expanding or improving it to meet currently unmet data needs
- 3) the resources available for data collection improvements

Usually there are insufficient resources to do everything that is needed, so choices must be made. The first step is to develop criteria for identifying the road segments for which traffic information is most useful. For example, real time information about a road that rarely experiences congestion will be of little use because the travel time will always be about the same unless there is some sort of incident. The second step is to collect data regarding these criteria for the road network and to use the criteria to identify the road segments for which information would have the greatest use and thus the highest value. This would include all uses, not just those related to traffic management center. All of this can be thought of as the demand side of the problem.

To examine the supply side of the problem, the first step is to determine what traffic monitoring facilities are already available for those road segments for which information would be most useful. If adequate monitoring is not already available, potential data collection systems² that could be used to obtain the desired data are identified. Given this supply and demand information for each segment, the most cost-effective method for acquiring needed data in each segment can be determined and its cost can be estimated.

Next, the various road segments are ranked and organized according to the ratio of their benefits to their costs. Potential funding sources are identified. The ranking is then used to construct a traffic surveillance improvement plan and funding program. An “ideal” traffic surveillance plan would include all investments with benefits greater than costs. But, because transportation funding generally is less than what would be needed to fund all such improvements, a “cost-constrained” traffic surveillance investment plan is developed as part of the overall transportation improvement plan. If unexpected funds become available, they are used for the highest ranked unfunded segment eligible for such funding. These steps are shown in Figure 1.

Criteria for Determining Where Traffic Surveillance Would Be Most Useful

Given that the priorities for surveillance coverage should relate to the benefits, the primary criteria for setting priorities should be the amount of delay and the variability of delay. Generally, the greater the average delay, the greater the variability in delay. But some locations, such as routes to beaches or weekend destinations, may generally have little delay but may sometimes have extreme delay. The maximum delay per vehicle is also something to consider. For example, 1000 people who are each delayed for 50 minutes probably experience more total disbenefit than 10,000 people who are each delayed 5 minutes, even though the total delay is the same in both cases. Another factor to consider is the existence of a generator of a large number of time-critical trips, such as an airport, stadium, or large entertainment facility. The existence of alternate routes that allow travelers to exploit any differences in travel time will also make travel time information more useful.

² These systems include sensors, sensor data processing, and all necessary communications.

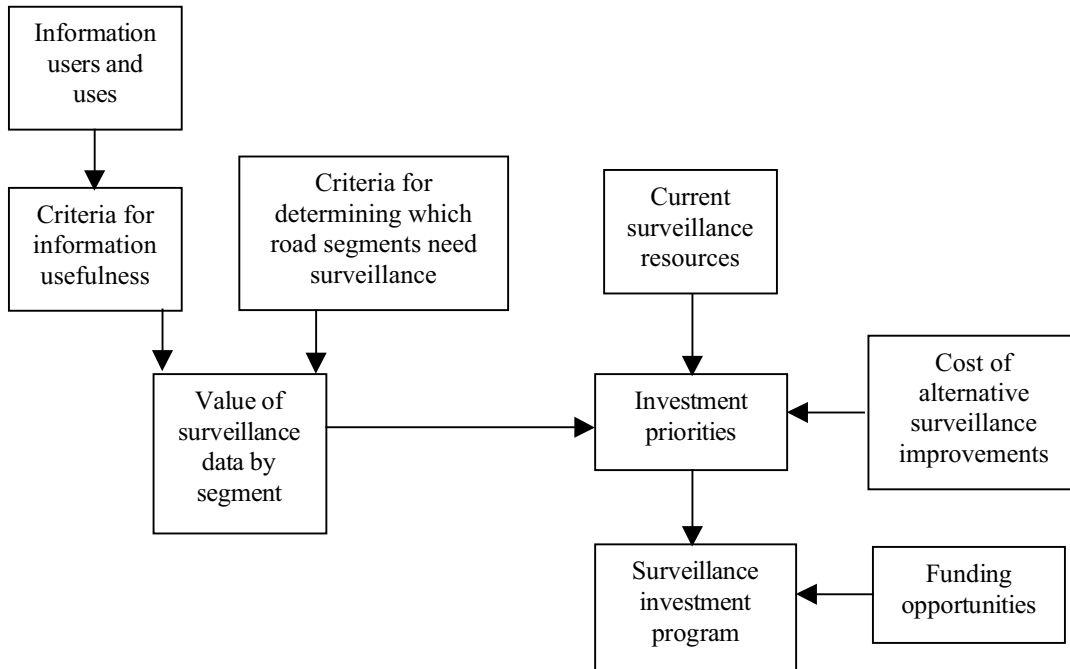


Figure B-1 Process for Developing a Traffic Data Investment Program

Development of Investment Program

Once costs have been estimated, each highway segment (or group of segments) can be positioned on a graph with the total delay on that segment on the vertical axis and the cost of a surveillance system on that segment on the horizontal axis as shown in Figure 3. The segments in Figure 3 are numbered in ascending order of the ratio of cost of their surveillance improvements to total delay, those above the line being the most cost-effective. This also allows easy selection of the most cost-effective group of projects to make with a given amount of funding. For example, if \$7 million were available, the best group of investments would be 1, 2, and 3. If an additional \$5 million became available, the best choice would be 5, because there would not be enough funding for 4. If funding became available that could only be used for a certain class of investments, it should be used for the most cost-effective investments that fell in that class and that had a total cost within the limit of the funding.

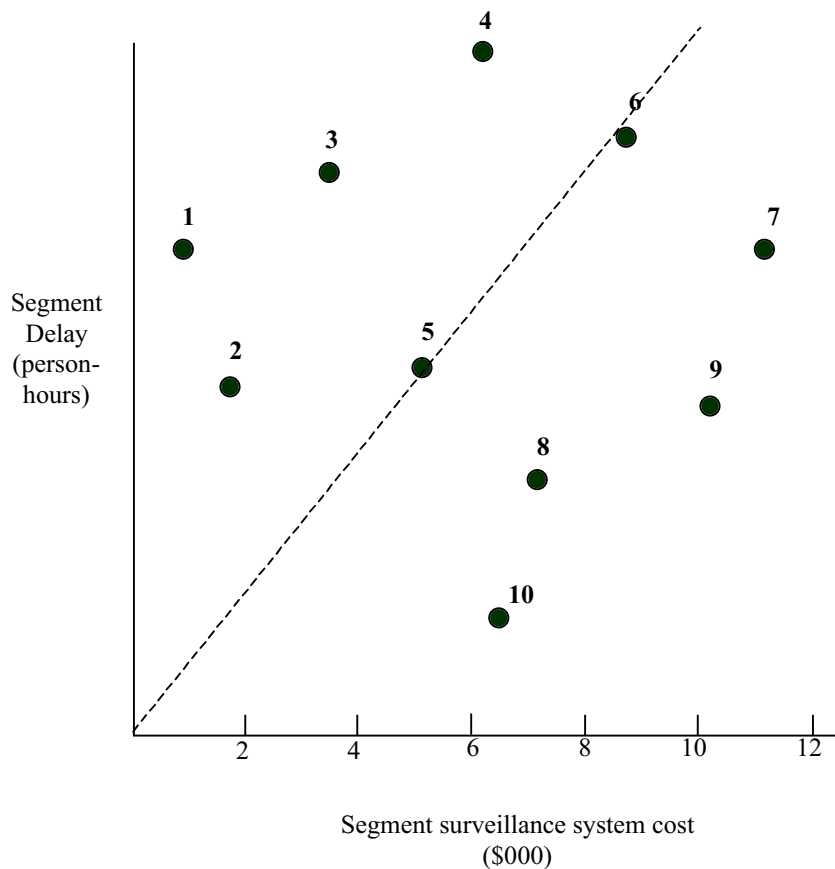


Figure B-2 Plot of the cost-effectiveness of alternate traffic surveillance investments