Research Report
Research Project T1803, Task 14
Arterial Surveillance

SURVEILLANCE OPTIONS FOR MONITORING ARTERIAL TRAFFIC CONDITIONS

by

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Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

June 2001

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 510.1	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Surveillance Options for Monitoring Arterial Traffic Conditions		5. REPORT DATE June 2001
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jennifer Nee, Mark E. Hallenbeck		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. Agreement T1803, Task 14
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370 Project Manager: Gary Ray, 360-705-7975, rayg@wsdot.wa.gov		13. TYPE OF REPORT AND PERIOD COVERED Research report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

The interest in and need for monitoring and reporting on arterial traffic conditions have increased with the growing implementation of both traffic management and traveler information systems. Because an increasing number of travelers are turning to the Internet for information, agencies are seeking ways to present arterial traffic data on this medium that are both understandable and useful to the public. At the same time, these same data must provide additional operational insight to public agency traffic management staff. However, although the idea of reporting arterial conditions is similar to that of monitoring and reporting freeway traffic conditions, different and innovative methods appear necessary for arterials because freeways and arterials differ in many aspects, particularly the effects of signals on traffic flow and speed.

The research approach for this project consists of a literature search, a series of personal interviews, and the development and user testing of alternative Internet-based information displays. The results of the study confirm that jurisdictions have a high level of interest in obtaining arterial traffic condition information for both arterial management and public information purposes. However, existing sensor coverage and equipment capabilities, as well as the manner in which data are (or are not) captured, require that much work be done before existing data sources can supply traffic data to Internet-based display systems. The study results provide some basic guidelines agencies can follow to obtain traffic information if no existing data sources are available, along with recommendations for presenting that arterial traffic data to the public.

17. KEY WORDS Arterial traffic information, surveillance, traffic monitoring		18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616	
19. SECURITY CLASSIF. (of this report) None	20. SECURITY CLASSIF. (of this page) None	21. NO. OF PAGES	22. PRICE

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CHAPTER 1
INTRODUCTION

The interest in and need for monitoring and reporting on arterial traffic conditions have increased with the growing implementation of both traffic management and traveler information systems. Tracking traffic conditions and reporting real-time travel information can help commuters make educated mode, route, and travel time choices. The findings from the USDOT's Intelligent Transportation Systems (ITS) User Acceptance Research Program and the Metropolitan Model Deployment Initiative (MMDI) Customer Satisfaction Evaluation indicated that drivers value traffic information in all forms because it decreases driver stress, saves time, and improves safety.

Traffic on arterial streets can be affected by heavy volumes, incidents, and special events just as much as on freeways. Arterials often serve as alternative routes for adjacent freeways or as parallel networks (e.g., the relationship between SR 99 and I-5 in the Puget Sound region of Washington State). As a result, for many locations, giving travelers knowledge about traffic conditions on arterials can be just as important as providing information on freeways. For example, a traveler may decide to approach and access the freeway by a less congested arterial. Similarly, commercial vehicles may benefit from knowing which exit and which route to take to avoid heavy traffic.

Traditionally, traffic monitoring and reporting have concentrated on freeway networks. In many metropolitan areas, freeways are equipped with detection and surveillance systems to aid in traffic management and to provide traveler information. However, the collection and reporting of arterial performance information has been much less common. While the visual imagery of real conditions from closed-circuit television

(CCTV) surveillance cameras is often used to verify problems, only a few cities currently provide these snapshots of arterial roadway traffic conditions to the public. Similarly, loop detectors (or video detectors acting as loops) are commonly used on arterials for operating signals, but the data collected are rarely used for public information displays. Although the idea of reporting arterial conditions is similar to that of monitoring and reporting freeway traffic conditions, different and innovative methods appear necessary for arterials because freeways and arterials differ in many aspects, particularly the effects of signals on traffic flow and speed.

REPORT PURPOSE

Because many agencies are new to arterial traffic performance monitoring, they need assistance in determining what they should do to collect and report arterial performance information. To address that need, the purpose of this project is provide some basic guidelines that agencies can follow to obtain traffic information if no existing data sources are available, along with recommendations for presenting that arterial traffic data to the public. The project goals and objectives are summarized in Table 1.

Also, an increasing number of travelers are turning to the Internet for information, agencies are seeking ways to present arterial traffic data on this medium that are both understandable and useful to the public. This study examined ways to display real-time arterial congestion information on the Internet that are meaningful to the public while providing additional operational insight to public agency traffic management staff. The intent was to understand the public's perceptions of the usefulness of various kinds of arterial traffic information and their reactions to various display formats for depicting traffic information. These measures were analyzed within the context of the data being collected for traffic management purposes, and the way those data were being displayed to meet agency needs.

In addition, the project examined the potential for various surveillance technologies to provide congestion and performance information and whether existing arterial surveillance system sources can supply traffic data to Internet-based display systems. This included a brief review of how agencies viewed the effectiveness of their existing traffic surveillance systems for management purposes.

Table 1. Project Goals and Objectives

Goals	**Objectives**	**Method of Information Gathering**	**Report Finding**
I. Identify ways to display real-time arterial congestion information on the Internet	Determine what other state and local agencies have done in providing arterial traffic information.	Conducted a state of the art review (see Chapter 2)	Examples of arterial traffic information provided by other state and local agencies
	Solicit public perception on the usefulness of various arterial traffic information measures, as well as their reactions to various display formats for depicting traffic information.	Administered a Web-based traveler survey (see Chapter 3)	Traveler's preference on types of traffic information and formats for displaying arterial traffic data on the Internet
II. Explore potential for various surveillance technologies to provide sufficient congestion or performance information	Identify existing practice in monitoring arterial traffic and data collection capability Investigate whether existing data sources can supply traffic data to Internet-based display systems.	Interviewed local agencies (see Chapter 4)	Information about local agencies' current practices and their perspectives about future enhancements to arterial traffic monitoring.
	Provide guidelines for obtaining arterial traffic data	Provided recommendations for implementation (see Chapter 5)	Recommended steps for agencies to follow to present arterial traffic data to the public

RESEARCH APPROACH

The research approach for this project consisted of a literature search, a series of personal interviews, and the development and user testing of alternative Internet-based information displays. A brief description of the these tasks is given below.

State-of-the-Art Review

Information on the current practices and experiences of other states and agencies that actively use ITS technology for arterial traffic management was collected through a literature review and informal interviews. The objective of this task was to gain a better understanding of other agencies' practices in gathering data for monitoring and reporting traffic conditions to the public.

Web-Based Traveler Survey

The intent of this task was to determine the public's perception of various kinds of arterial traffic information and their reactions to various formats for displaying traffic information. On the basis of information obtained from local agency interviews and the state-of-the-art review, alternative prototype displays of arterial congestion data were prepared and presented to the general public as part of a Web-based survey. The intent of the survey was to test whether the general public sees value in this type of display and can use this type of information to effectively differentiate among levels of congestion, and to determine which types of displays were preferred. The Web-based survey was designed to focus on travelers who are not only Internet users but who also possess an interest in accessing traffic information on-line.

Users were given a questionnaire that presented arterial congestion in various formats and asked questions regarding whether they liked or disliked each of the transportation data displays. The on-line survey questionnaire was posted at four Washington State Department of Transportation (WSDOT) traveler information Web sites:

- WSDOT FLOW map - www.wsdot.wa.gov/PugetSoundTraffic/
- WSDOT Freeway Cameras - www.wsdot.wa.gov/PugetSoundTraffic/cameras/
- Bellevue Traffic Camera - traffic.wsdot.wa.gov/nwflow/bellevue/
- Seattle Traffic Camera - traffic.wsdot.wa.gov/nwflow/ seattle /

Users of these Web sites filled out the on-line survey by clicking on a banner on the Web sites. Survey respondents answered questions using the dichotomous (yes or no response) and multiple choice (one out of four variables) scaling methods. The Bellevue street network, bounded by 156th Ave on the east, Coal Creek Parkway on the south, 110th Ave on the west, and NE 24th on the north, was used as the display subject for all prototype examples.

Local Agency Interviews

This task examined the current state of the region's arterial surveillance practices. Interviews were conducted to learn about the current practices and desires of agency staff. Subject areas included the following:

- existing arterial traffic controls
- the current availability of and desired levels of real-time traffic monitoring capabilities
- current and desired sensor coverage
- the surveillance technologies currently used and staff attitudes towards those technologies
- the communications capabilities that exist

- the current use of traffic data
- how arterial traffic information is currently reported, and ways that agencies wish to report it in the future.

For cities such as Seattle and Bellevue, which provide video snapshots of arterial traffic conditions to the public via the Internet, it was important to identify their experiences in using this technology and their methods for displaying and disseminating traffic management and public information (e.g., what these agencies considered to be the best and worst features of their current systems). It was also important to examine the public feedback that has already resulted from the traffic information that is currently displayed.

The project team also assessed the goals of the transportation agencies in monitoring arterial congestion to determine whether the emphasis of those agencies was on arterial and/or intersection activities and whether the traffic information collected was intended primarily for use by transportation system operators or by the public.

Recommendations for Implementation

The project team summarized common deficiencies in arterial traffic monitoring and data collection identified by agency staff. A summary of recommended steps to rectify those deficiencies was then prepared to assist agencies in meeting both public and agency desires.

REPORT CONTENT

The project findings and conclusions are documented in the following chapters:

- Chapter 2 – national state-of-the-art review on monitoring and reporting arterial traffic conditions

- Chapter 3 – description of survey results on public preferences for arterial information, including reactions to various display formats for presenting arterial congestion information
- Chapter 4 – description of local agencies' existing arterial surveillance practice and their perspectives about future enhancements to arterial traffic condition monitoring
- Chapter 5 – recommendations and guidelines for agencies regarding the collection and presentation of arterial traffic data to the public.

CHAPTER 2
STATE-OF-THE-ART REVIEW

The experiences of other state and local agencies in providing arterial traffic information were reviewed to gain a better understanding of their practices for gathering data for operational purposes and to learn how they were presenting that information to the public. The cities polled for this project shared the goals of moving traffic more efficiently, being responsive to future changes in traffic demand, and giving motorists better information as a means of assisting them in making better travel decisions. The review addressed both how agencies collect traffic surveillance data and how they report arterial traffic flow conditions.

There is no standard practice among traffic departments across the country for providing arterial traffic condition information. Each agency has to be creative while working within its budget and other constraints to respond to needs that are unique to its region, geography, institutional philosophy, traffic patterns, and surveillance capabilities. This can be frustrating for agencies starting from scratch and looking for a model to follow, especially since most agencies have developed unique software packages to capture and report data within the context of their own hardware configurations and reporting requirements.

Many cities across the nation are in the midst of upgrading their arterial traffic control systems. This chapter discusses the basic arterial traffic management systems of seven U.S. cities. It presents the type of arterial surveillance they have and describes how they are using the collected data. It also presents two international examples of public distribution of arterial performance information.

TRAFFIC SYSTEM SURVEILLANCE AND CONTROL DESCRIPTIONS

Each of the arterial traffic control systems briefly discussed below monitors facility performance. The data collected from that monitoring are used to make control decisions for the facilities and are presented in some form to the general public. The traffic surveillance hardware used for monitoring varies from agency to agency, although three basic technologies are most common: loop detection, closed-circuit television (CCTV), and video image based vehicle detection such as Autoscope™. A complete discussion of the advantages and disadvantages of the available surveillance technologies is beyond the scope of this report. A brief summary of the most common technologies is included in Chapter 4 of this report. More complete discussions of surveillance technologies can be found in various references. [1, 2, 3, 4]

Summary

In general, agencies choose detector technologies on the basis of experience and preferences. Climate and operational characteristics (such as how frequently lane channelization changes) tend to play a major role in the selection of surveillance technology, particularly in the choice between traditional loop technology and the more modern, non-intrusive technologies such as video detection. Although loop detectors and video detection are most widely used, other technologies are being considered and tested. For example, Montgomery County, Maryland, is testing radar and sonic detectors, while Boston is using laser detectors in a corridor where traffic speeds fall as low as 4 mph because loop detectors are not effective at such low speeds.

Conventional camera images are highly valued by many agencies both for their ability to verify current traffic conditions and for their use in providing traffic condition information to the public. For many of the interviewed agencies, CCTV images on the Internet were the first major ITS deployment shared with the public. All agencies examined have had good experiences with camera images and have received positive feedback from the public. The public can readily identify with camera images, whereas many people require a learning period to fully understand information being displayed in other forms, such as color-coded flow maps.

Most agencies indicate that CCTV images are a great tool for verifying traffic conditions and helping to understand the causes of those conditions, but only a few agencies use CCTV as their primary surveillance tool for traffic control purposes. Most agencies with CCTV continue to use conventional loop or video image detector data to operate their traffic signal control algorithms. These data are then supplemented by additional measures such as travel times or CCTV images to monitor the effects of changes in control strategies and/or verify the cause of traffic problems.

Specific examples are presented below.

Oakland County, Michigan (Detroit Area)

As part of its Faster and Safer Travel Through Routing and Advanced Controls (FAST-TRAC) system, the Road Commission for Oakland County (RCOC) in Michigan adopted a video-based vehicle detection system (Autoscope devices). These devices are used to collect real-time traffic flow data, which are both analyzed by a computer in a nearby control box and transmitted to one of five regional signal control computers and to a central traffic operations center (TOC). These data are supplemented by CCTV cameras placed to provide operators with views of congestion and incidents on specific arterial streets.

The video detector data are used as input to FAST-TRAC algorithms for adjusting traffic signals to match network-wide traffic flow. These algorithms can also be adjusted by the staff at the central TOC on the basis of images from the CCTV system or other information that becomes available to the center staff. This additional capability allows the TOC traffic engineers to monitor both specific intersections and the region as a whole, thus providing a better selection of control strategies. Finally, the RCOC maintains a database of the traffic data collected to support various planning and operational studies (such as retiming of the signal plans).

San Jose, California (San Francisco Bay Area)

The City of San Jose's Traffic Signal Management Program (TSMP) unit uses real-time traffic data collected from loop detectors to operate traffic responsive signal timing plans. Operations staff also use cameras in conjunction with the loop detectors to provide data necessary to make appropriate timing changes for current traffic conditions and to monitor the operation of traffic signal equipment.

Honolulu, Hawaii

The TraffiCenter in Honolulu operates and maintains 350 networked traffic signals at intersections on state and county roads. TraffiCenter uses a centralized system in which operators can easily modify, test, analyze, monitor, and optimize remote systems from the center.

Sixty-eight traffic cameras are installed at critical locations in Honolulu to supply information used in this operation. The TraffiCenter views its traffic cameras as a great tool in helping operators verify roadway conditions. The traffic control system operators in Honolulu rely heavily on video images to make judgments about traffic conditions and decisions about possible remedies. Staff are currently looking to adopt machine vision technology to improve detection capabilities. Staff expect to be able to collect vehicle counts, vehicle speeds, lane occupancy, and queue measurements from this technology.

Las Vegas, Nevada

In Las Vegas, 42 CCTV cameras are located on high volume corridors at strategic intersections. Video images are viewed at the traffic center on a wall with six large TV displays. System loop detectors are being placed at the far side of signalized intersections to count vehicles exiting the intersection. Customized software, which will be used to communicate with the various controllers and to control the CCTV cameras, is currently in design. The Las Vegas signal interconnection system is being converted from hard-wired connections to microwave communications, with a completion date of some time in 2002. Ten towers around the Las Vegas valley will beam information between the signals and a hub, which will then pass the information to the traffic management center.

Montgomery County, Maryland (Washington, D.C. area)

The Advanced Transportation Management System (ATMS) of the Department of Public Works and Transportation in Montgomery County, Maryland, currently uses traditional inductive loop detectors for traffic data collection and surveillance. Advanced traffic responsive traffic signal control is operational for up to 1,500 signals (700 on-line). In addition, 80 cameras are on-line equipped with pan, tilt, and zoom capabilities. These cameras provide the TMC with visual confirmation of problems detected by the loop system, as well as more descriptive information about congestion causes at known problem locations.

Montgomery County also operates a Web site for traveler information. A planned enhancement to the Web site will include real-time traffic data from the ATMS's graphical information system (GIS).

Boston, Massachusetts

The Massachusetts State DOT is completing construction of CCTV cameras and mid-block loop and laser detectors on two arterials running parallel to a freeway. Information from the loops will be integrated into a CORSIM-based traffic simulation model, running in real time. Output from this model will be used to post estimated travel times on VMS signs.

INFORMATION SHARING AMONG AGENCIES

Because arterials often cross jurisdictional boundaries, some agencies' arterial traffic control and monitoring programs have expanded to include multi-agency efforts, in which arterial traffic management is coordinated across jurisdictional boundaries within a particular corridor, region, or area. For example, the Silicon Valley Smart Corridor project in California is facilitating multi-agency cooperation by coordinating signal timing plans across jurisdictional boundaries along a 15-mile corridor with a mixture of freeways and local arterial streets. Coordination takes place both during normal control system operations and during incidents and special events. Collected traffic information is shared with neighboring jurisdictions in the Silicon Valley.

The objective of the project is to optimize the overall operation of transportation facilities in the corridor and to ensure seamless travel across jurisdictional boundaries. The multi-phased project is intended to create a network of traffic detection loops and monitoring cameras that provide real-time data to engineers, instantaneous changes to signal timing across jurisdictional boundaries, and up-to-the-minute data to motorists. Since each agency has its own unique traffic management system, a data exchange network (DEN) translates all data and provides a common interface for all users.

Another example of multi-agency cooperation in sharing traffic information and coordinating signal timing across jurisdictional boundaries is the Las Vegas Area Computer Traffic System (LVACTS). LVACTS is a multi-jurisdictional effort to coordinate all the signals in the Las Vegas Valley using a microwave interconnection system. Traffic signals in the Las Vegas valley are jointly controlled by a coalition of local jurisdictions.

In Montgomery County, Maryland, snapshots of arterial traffic flow conditions are shared with the county police and with the Fire and Rescue Emergency Communications Center (ECC) to aid it in incident response. The Division of Highway Services also has a video feed from the traffic management center (TMC) to monitor road conditions. This connection has proved to be very useful during adverse weather. In addition, local broadcast television stations (NBC, CBS, ABC, Fox and News Channel 8) have dedicated links directly from the TMC. The TMC also shares its video with the Maryland Statewide Operations Center (SOC) and the Federal Highway Administration.

<u>REPORTING ARTERIAL INFORMATION</u>

Opinions differ regarding the value of information, and where and how it should be presented. Agreement is possible on the fact that the information needs to be given at times, locations, and via mechanisms that allow it to be used effectively. These conditions change depending on when during the trip information is received.

It is also agreed that data must be accurate, timely, and reliable. Information should be updated frequently and should be as accurate as possible to build trust and credibility with the public. Table 2 includes a variety of examples of how traffic conditions are being presented. The table includes Web site URLs that allow the reader to view these systems in action. Finally, there is general agreement that building flexibility into any system is good so that it is adaptable to future needs, changes, and new technologies.

As can be seen in Table 2, presentation of arterial traffic information to the public varies among agencies. Some agencies provide information via the Internet, while others provide information via variable message signs. A few supplement these mechanisms with less common technologies such as kiosks at train stations and other public locations.

Internet sites most commonly include either color-coded flow maps or CCTV images, although some agencies provide a combination of both types of data. Traffic condition maps can be color coded according to any of the commonly available traffic performance parameters (speed, lane occupancy, volume) and can also indicate specific accident or construction locations that are likely to produce congestion. In many cases, the public is not told directly what units of measure are being used. Instead, roadways experiencing performance problems are simply labeled as “congested” or “heavy” (or some other term that is easily understood by the public.

Table 2. Selected Examples of On-line Arterial Traffic Information

	Web Site for Arterial Traffic Information	Types of Online Traffic Information			
		Measurement	**Video Image**	**Prediction**	**Text Reporting**
Bellevue, Washington Seattle, Washington	http://www.wsdot.wa.gov/PugetSoundTraffic/cameras/		Snapshots		
Honolulu, Hawaii	http://www.eng.hawaii.edu/Trafficam/		Snapshots		
Las Vegas, Nevada	http://www.smartconnect.net/		Full motion		
San Jose, California	http://www.ci.san-jose.ca.us/traffic/sj_down_inv.html	Color coded flow map - Volume - Speed - Level of congestion			
Oakland County, Michigan	http://www2.rcocweb.org/	Color coded flow map - Level of congestion	Snapshots		
Downtown area: - Cincinnati, Ohio - Minneapolis and St. Paul, Minnesota - Philadelphia, Pennsylvania - Washington DC Area	http://www.smartraveler.com/		Snapshots (Washington DC area only).	Travel time for selected routes (Washington DC area only)	Current traffic condition (e.g., delays, incidents)
Montgomery County, Maryland	http://www.dpwt.com/TraffPkgDiv/		Snapshots available for selected sites.		Current traffic condition (e.g., delays, incidents)
Athens, Greece	http://frida.transport.civil.ntua.gr/map/index.htmls	Color coded flow map - Volume - Speed - Level of congestion		Travel time for selected routes	
Belfast, Northern Ireland	http://www.ruc.police.uk/		Full motion		
Nottingham, England	http://utc.nottscc.gov.uk/		Snapshots		

In a few cases, travel times are predicted. Some variable message signs may display the travel time to the next major freeway exit or destination. On freeways, specific routing suggestions may be included with the travel time information. On the Internet, travel times are occasionally available between origins and destination selected by the user, although these systems are rarely available for arterial networks.

Although most agencies are planning to provide a flow map, few agencies currently provide arterial data to the public in this fashion. More common is the availability of CCTV images. Camera images include recent still images on the Internet, full motion video via the Internet, and full motion video displayed over traditional television channels.

Traffic management staff in Honolulu expressed a common attitude regarding arterial information for the public. They felt that flow maps required an extra interpretation step that camera images could eliminate and, consequently, decided that cameras were a more reliable method of disseminating information. CCTV images of traffic conditions at major intersections throughout Honolulu are available on its Web site, as well as on news broadcasts. In addition, Honolulu plans to use machine vision technology to collect information to be processed and color-coded on a map to display area-wide flow conditions. In Belfast, Northern Ireland, full motion video images of live traffic conditions are presented via the Internet. In Nottingham, England, live traffic conditions are presented as still camera images. In Athens, Greece, predicted travel times and text reporting for arterial networks are also of interest.

Not all agencies agree that cameras are the best approach to public information dissemination for arterials. For example, San Jose, California, provides a color-coded flow map that can show volume, speed, and level of congestion on its Web site based on the user's choice. The Road Commission for Oakland County (RCOC) in Michigan displays the level of congestion via the Web using saturation flow information obtained from its traffic control system stop bar loops.

Still others employ innovative methods to convey traffic information to the driver on the road. While Boston is planning to develop an on-line flow map, it will initially display travel time estimates on VMS signs to inform interstate drivers of the travel times on two parallel arterials. Its stated intent is to help drivers in freeway queues decide whether to stay on the freeway or divert to adjacent arterials. In Maricopa County, Arizona, in addition to VMS signs on four arterials, kiosks in transit stations, and freeway cameras on the Internet, the county's DOT has partnered with private firms to broadcast camera images on dedicated cable channels and is working on providing traffic messages tailored to subscribers' preferred routes via email, pager, handheld computer devices, cell phone, and various other personal technology formats.

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[1] A Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems, by The Vehicle Detector Clearinghouse, Fall 2000, < http://www.nmsu.edu/~traffic/>

[2] An Assessment of Data Collection Methodologies and Equipment for ISTEA Congestion Management System Requirements, January 1998.

[3] Klein, L. A. and M.R. Kelley, *Detection Technology for IVHS, Vol. 1: Final Report*, FHWA-RD-95-100, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., December 1996.

[4] Kranig, J., E. Minge, and C. Jones, *Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies*, FHWA-PL-97-018, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., May 1997.

CHAPTER 3
WEB SURVEY RESULTS

This chapter discusses the results of a Web-based user survey of the public's arterial information needs, attitudes, and desires. The user survey primarily focused on the public's perceptions of the usefulness of various types of arterial traffic information and the respondents' reactions to various display formats for depicting traffic information. A total of 610 on-line survey entries were received during the five-week Web survey session, from May 31, 2000, through July 5, 2000. The survey was available through four WSDOT traveler information Web-sites: the FLOW map page, the Freeway Camera page, the Bellevue Traffic Camera page, and the Seattle Traffic Camera page. A copy of the survey is included in Appendix A. Survey responses were typically submitted on weekdays during the afternoon peak commute hours (e.g., 2:00 PM to 7:00 PM).

The results are grouped into six sections within this chapter. These sections are as follows.

- First, a profile of the characteristics of survey respondents is provided. This includes their distribution by gender, age, and education level, their familiarity with obtaining traffic conditions on the Internet, and the effect that their previous experience at accessing on-line traffic information has had on the preferences they stated in the survey.
- A description is then presented of how survey participants rated the usefulness of different types of traffic information in helping them understand traffic conditions on city streets. The types of traffic information tested include the following:
    - location of possible incidents
    - level of congestion
    - speed of traffic
    - traffic volumes
    - camera snapshots
    - travel time prediction

  - live video of the roadway.

- The third section discusses which devices the respondents preferred to use to obtain arterial traffic information. Devices mentioned as part of the survey include the following:

  - the Web via desktop or laptop computers
  - the Web via handheld and palmtop devices
  - radio
  - telephone
  - in-vehicle devices
  - television
  - paging devices
  - kiosks.

- Next is discussed whether users preferred getting information about actual and current traffic conditions, or about how current traffic conditions deviate from the typical situation (i.e., whether conditions are better or worse than usual)

- The fifth section of this chapter describes how respondents reacted to different types of illustrations of traffic conditions. The following display formats for arterial traffic information were tested:

  - Map A. traffic conditions for an entire intersection, regardless of the direction of traffic
  - Map B. traffic conditions for each approach at an intersection using an arrow
  - Map C. traffic conditions for each direction along roadways
  - Map D. camera images of traffic conditions at intersections and/or mid-block.

  This section then presents respondents' preferred display format, including a comparison of response patterns among various groups, from frequent users to non-users of on-line traffic information

The survey also allowed respondents to make general comments. Where appropriate, the statistical results presented in each section are supplemented by these viewpoints to provide a better understanding about responses.

CHARACTERISTICS OF SURVEY RESPONDENTS

Demographic Characteristics

The distribution of survey respondents by gender, age, and education level is included in Figure 1. The majority of respondents were male (78 percent). Most respondents (88 percent) were 50 or younger. Eighty percent of survey respondents possessed a college degree or post-graduate education.

Familiarity with Getting Traffic Conditions on the Internet

Most of the respondents were already somewhat familiar with getting arterial traffic condition information on the Internet. Figure 2 shows that over 80 percent of respondents had previously obtained camera snapshots of traffic conditions on city streets such as in the cities of Seattle and Bellevue via the Web. Of these respondents, 45 percent frequently (e.g., 3 to 7 days per week) used camera snapshots for checking traffic conditions on city streets, 25 percent used them occasionally (e.g., 1 to 2 days per week), and 30 percent rarely accessed the information.

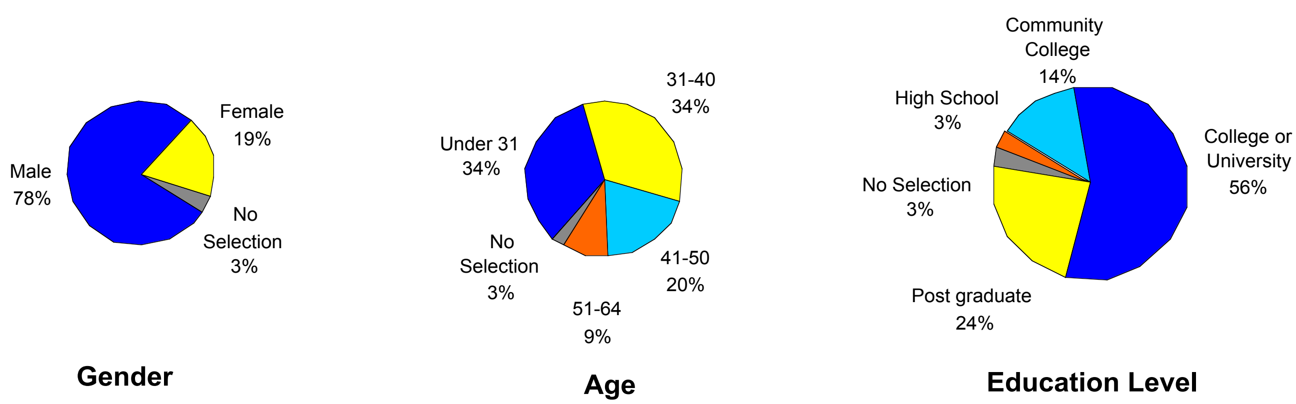

Figure 1. Demographic Characteristics

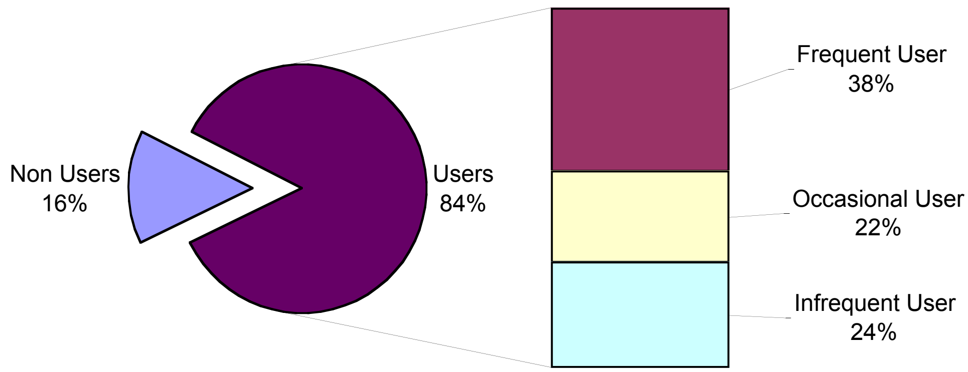

Figure 2. Usage of Traffic Information via the Web

<u>Prior Experience Accessing On-line Traffic Information</u>

As shown in Figure 2, the majority of respondents had previous experience accessing on-line traffic information. This is not surprising since the survey itself was Web based. The respondents' comments suggested that they were familiar with the color-coded flow map and camera snapshots for the freeway network, and that a significant number of solicited responses for this survey were based on their experience and interaction with the existing Puget Sound area freeway traffic information Web site. In fact, the overall response to this survey revealed that the current Web site provided by the WSDOT is very well received by the public in terms of display format and level of detail. The effect of their experiences on how they rated various display formats is discussed later in the section.

Respondent Attitude

Respondents were very active about providing comments (~200) for various topics in this survey. They not only completed the questionnaire, many respondents provided the reasoning for their input (e.g., why they picked one display format over another) or gave suggestions for improving Web sites (e.g., what they would find useful, such as describing how city arterial volumes affect Interstates). Meanwhile, they were also excited about this research effort and wanted arterial information. The following is a selected list of comments provided by respondents:

> I think the current site is impressive. I would be blown away with any of the above choices. They are that much more useful.
>
> Wow. Well, thanks for doing this research! You folks seem to be on the right track!
>
> This is a great survey. Step one is asking input from people, and it shows that you care about providing insight into this crappy traffic problem we have here. Step two is acting on it and providing the info.

TYPE OF TRAFFIC INFORMATION

One of the important elements in providing traveler information is to adopt measures that travelers find helpful in depicting roadway traffic conditions. Thus, the survey participants were asked to rate the usefulness of the following measures in helping them understand traffic conditions on the city streets:

- location of possible incidents
- level of congestion
- speed of traffic
- traffic volumes
- camera snapshots

- travel time prediction
- live video of roadway.

Figure 3 shows that each of these measures was considered useful by the majority of respondents (70 to 97 percent). Among the listed measures in the survey, the one reported most useful was the ability to show the location of a traffic accident. Almost 90 percent of the respondents indicated that knowing the location of an incident would be "very useful" traffic information. Other incident-related details were also requested by respondents as part of their frequent survey comments. Respondents tended to request information on the type of incident, its time of occurrence, and a predicted time for incident clearance. These additional items help travelers better understand the cause of current traffic congestion and provide clues about the size and duration of congestion impacts that can then be used to help determine whether they should make alternative travel plans (e.g., taking an alternative route would be more useful in the case of a three-car, injury accident blocking two lanes than for a simple fender-bender).

Other possible measures of arterial performance were all perceived positively but of less usefulness than the incident information. Travel speeds, traffic volumes, camera views, and travel time predictions received relatively similar responses. The two lowest rated measures were the camera images, although live streaming video may help users determine whether they are looking at real congestion or just cars waiting at a light on an arterial.

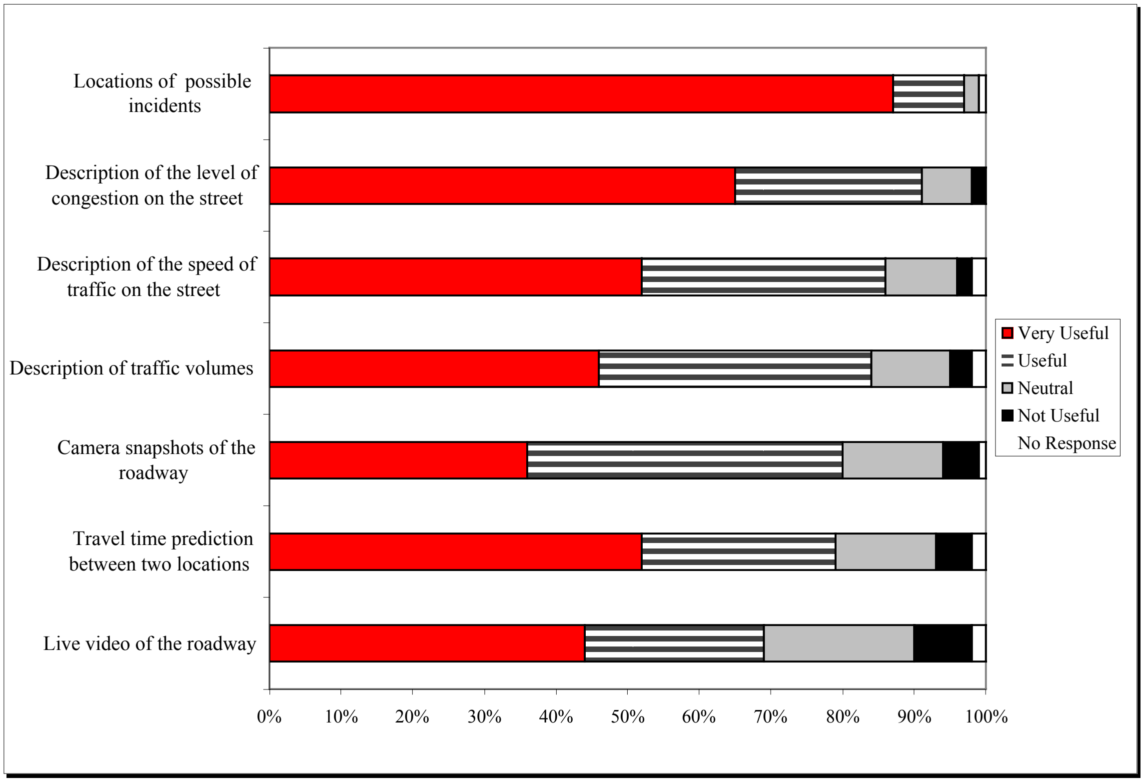

Figure 3. Ratings on Type of Traffic Information

Survey results also suggested that when travelers are planning a trip, warnings of incidents, construction, and special events, as well as possible alternative routes, are useful supplements to typical traffic measures that describe current conditions. Other measures mentioned by respondents included queue lengths, forecasts of future congestion (e.g., 15-minute, 1-hour out), and creation of a comment section for commuters who have been through a trouble spot, so that they can share information with others (for example, a "chat room" for congestion information). One respondent commented on including information about how volumes on arterials that lead to major destinations affect freeways and vice versa.

DEVICES FOR DELIVERING TRAFFIC INFORMATION

This section addresses the importance of presenting traffic conditions on devices (and in a manner) desired by the public. Traffic information can be packaged differently via different devices. For instance, visual/graphic presentation of traffic information is emphasized on the Web. Geographic coverage can be described in more depth on the Web than over a radio broadcast. Therefore, it is useful to find out how travelers rate the usefulness of a variety of information delivery devices. The devices respondents were asked about include the following:

- the Web via desktop or laptop computers
- the Web via handheld and palmtop devices
- radio
- telephone
- in-vehicle devices
- television
- pagers
- Kiosks.

Not surprisingly since the survey was Web based, the majority of respondents thought that the Web via desktop or laptop computers was an effective medium for getting traffic information (see Figure 4). In contrast, obtaining traffic information from the Web via handheld and palmtop devices was not perceived to be nearly as useful. Reasons for this observation may be associated with usability and cost issues. Currently, only selected Web sites are reformatted for hand held devices. Also, equipment and air time costs appear to have limited respondents' experiences with handheld and palmtop devices.

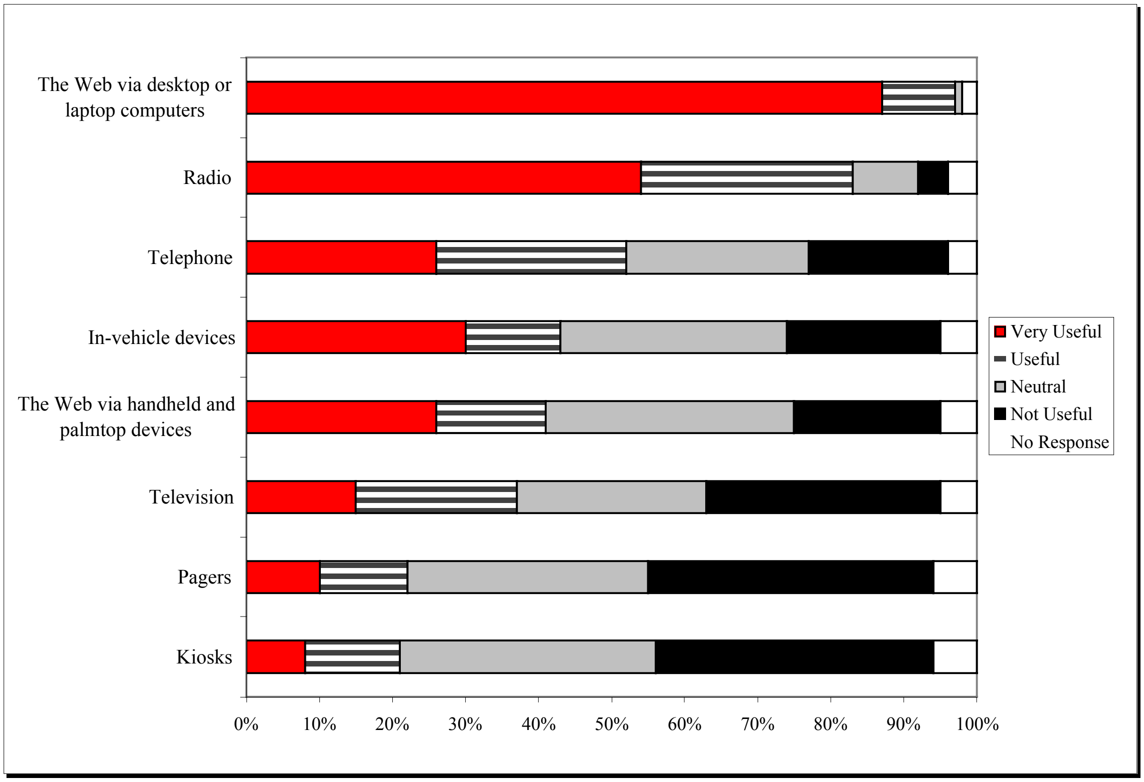

Figure 4. Ratings on Devices for Delivering Traffic Information

For those respondents who were already using handhelds to check traffic conditions from clipped Web sites, the experience seemed positive. Some respondents commented that they would be interested in owning such a device if traffic information were available. It will be interesting to see whether the interest in in-vehicle devices and the Web via handheld and palmtop devices is significantly affected once these devices and their operation are more refined.

As shown by the survey results, radio reports are another preferred traffic information delivery medium. However, respondents felt that this medium's usefulness could be enhanced by more frequent radio traffic reports. The survey results also revealed that variable message signs (VMS) can be useful in delivering traffic condition information as well. Comparatively, the other popular communication media, telephone and television, were viewed as less useful for getting traffic information. Some respondents indicated that the traffic flow maps shown on television often flip too quickly. Of the choices presented in the survey, pagers and kiosks were the least favorite devices for delivering traffic information. Note that some people who had "neutral" or "not-useful" responses to a device might simply have had no experience with the device.

ACTUAL VERSUS HISTORICAL TRAFFIC INFORMATION

On being asked whether they preferred receiving current traffic conditions or a comparison to a typical condition, 80 percent of all respondents preferred information that tells actual, current conditions for arterial streets (e.g., heavy, moderate, or light). Fewer people preferred knowing how current traffic conditions deviate from the typical situation (e.g., if current volume or speed is better or worse than usual for a certain time of day). As Figure 5 shows, this preference was universal for all types of users, from frequent users to infrequent users to even non-users.

In addition to presenting actual, current traffic information, a significant number of survey respondents requested that some measure of comparison of current conditions be made against "normal" (i.e., for that time of day and day of week) traffic patterns. This information was viewed as less important than actual conditions, but still quite useful, especially for pre-trip planning.

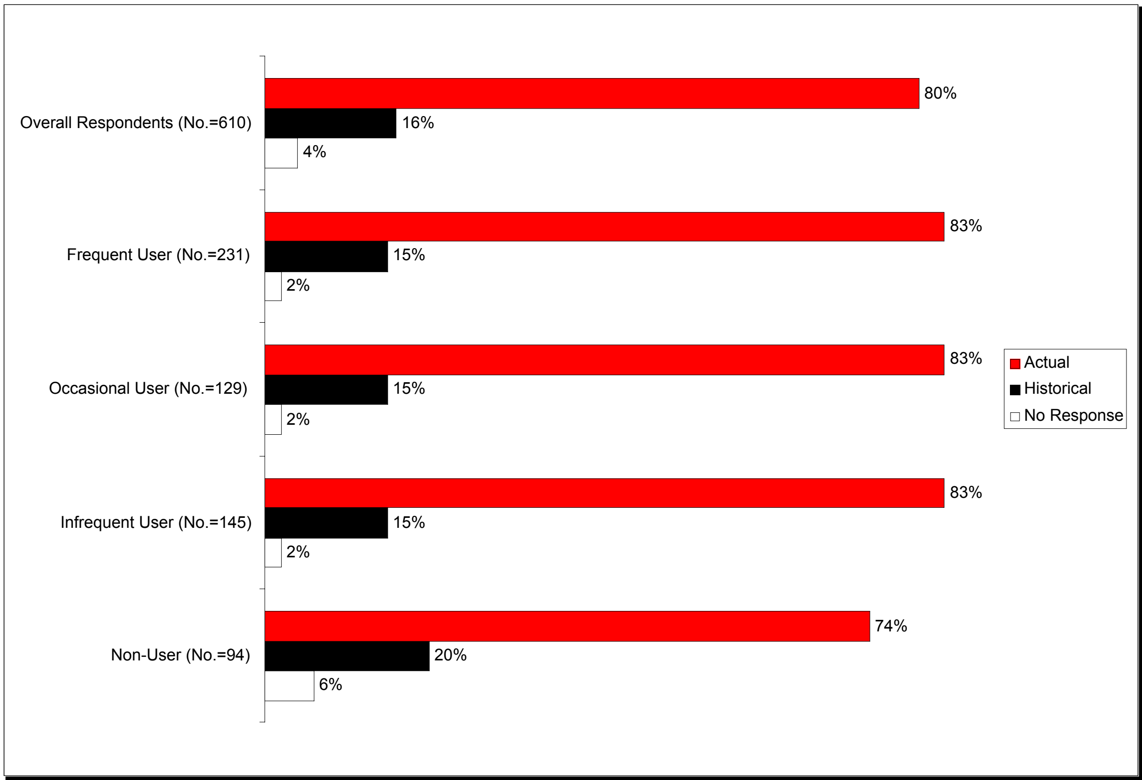

Figure 5. Preference for Type of Information

DISPLAY FORMAT

One aspect of this analysis was to determine how users react to different display formats for arterial traffic information. Four display formats were presented to users in the survey. Respondents were asked to rate the usefulness of each format. Having asked about the usefulness of each of the display formats, the survey then asked respondents which format they preferred. The following explains what each of the displays entailed and the public's response.

<u>Type of Display Format</u>

<u>Map A. Traffic level for an entire intersection, regardless of the direction of traffic</u>

In Map A, shown in Figure 6, the average traffic level was color-coded and presented for an entire intersection; there was no specific information for each direction of traffic. For example, a red circle indicated that the traffic at that intersection is generally heavy (or more congested than usual), a yellow circle indicated that the traffic at that intersection is moderate (or as expected at that time of the day).

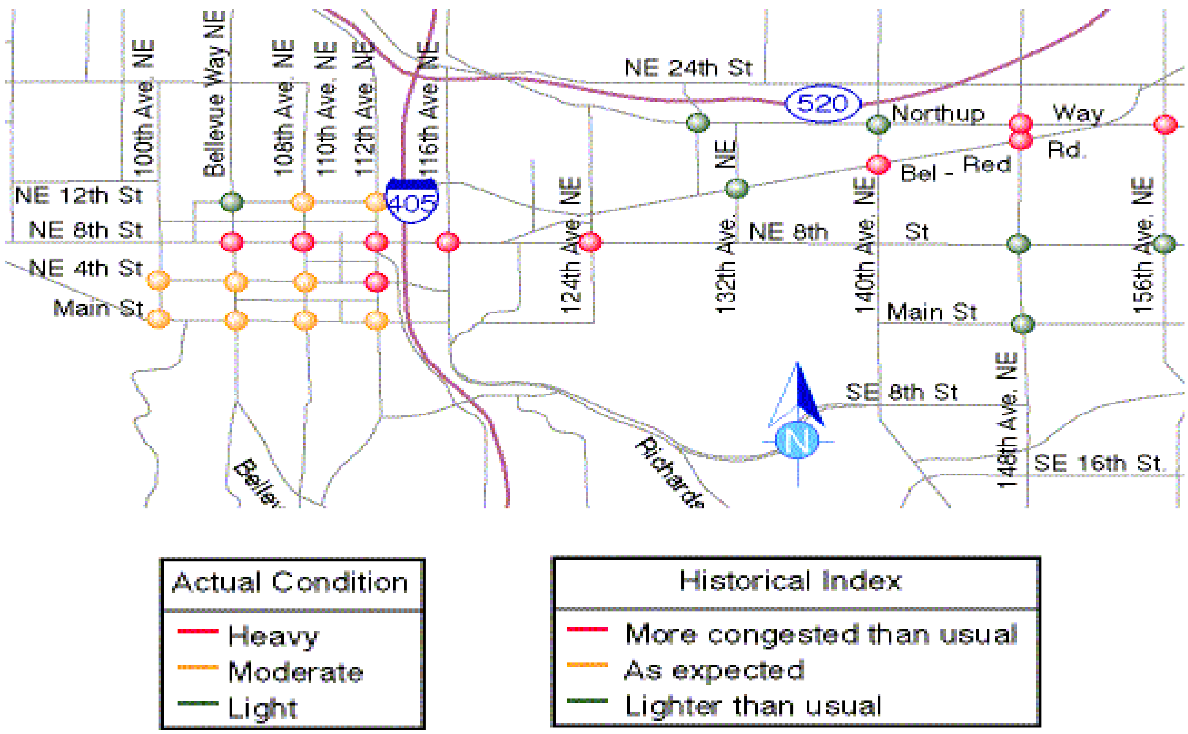

Figure 6. Map A - Traffic Level for an Entire Intersection, Regardless of the Direction of Traffic

__**Map B. Traffic level for each approach at an intersection using an arrow**__

In Map B, the average traffic level for an entire intersection was replaced by information for each approach at an intersection (see Figure 7). Traffic conditions from each approach were color-coded, and the direction of the traffic was indicated by an arrow. For example, traffic heading westbound toward the intersection might be moderate (or as expected), while northbound traffic might be heavy (or more congested than usual).

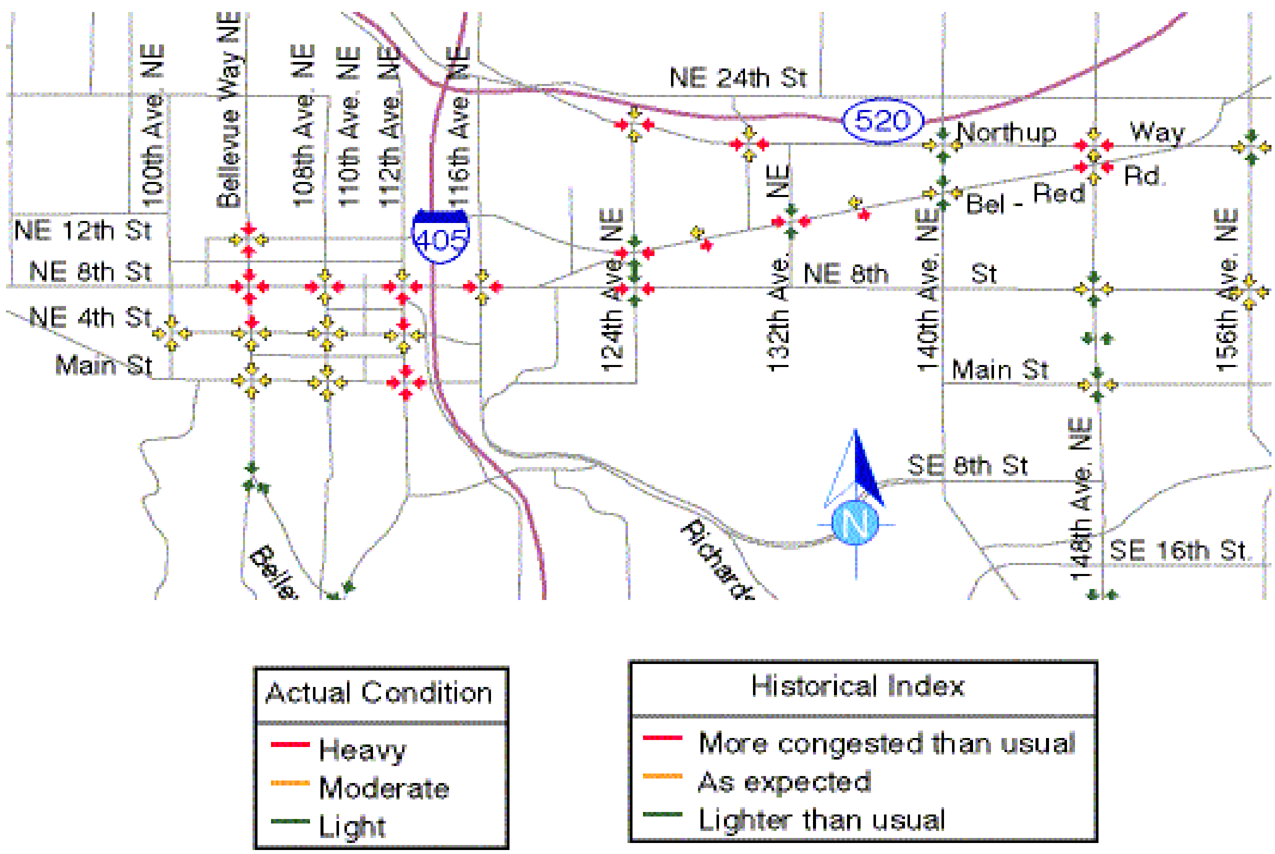

Figure 7. Map B - Traffic Level for Each Approach at an Intersection Using an Arrow

Map C. Traffic condition for each direction along roadways

In Figure 8, Map C shows a format that is similar to the current Puget Sound area real time flow map for the freeway network (www.wsdot.wa.gov/PugetSoundTraffic/), in which traffic congestion level is color-coded and shown for each direction and along the entire roadway segment.

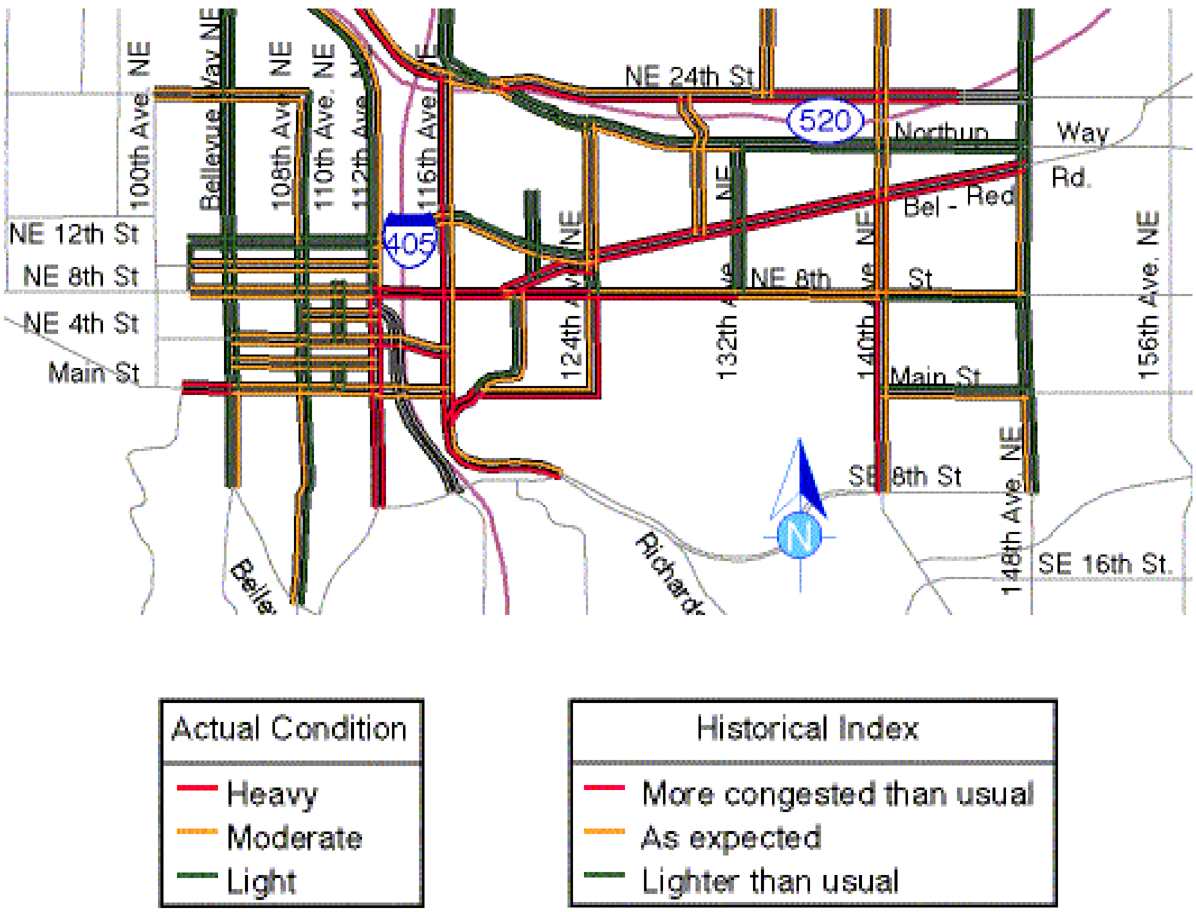

Figure 8. Map C - Traffic Level for Each Direction Along Roadways

Map D. Camera images of traffic conditions at intersections / mid-block

Map D illustrates still camera snapshots of traffic conditions at intersections and/or mid-block (see Figure 9). Each camera shows roadway conditions one direction at a time.

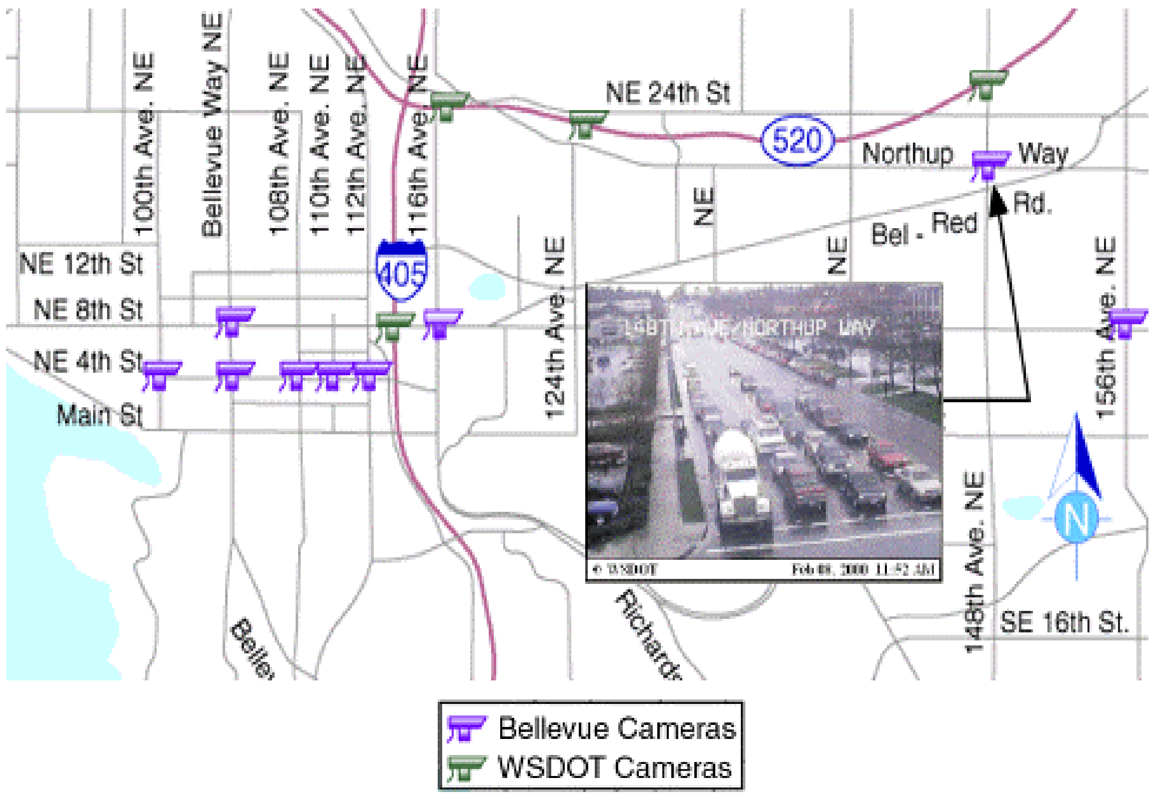

Figure 9. Map D - Camera Images of Traffic Conditions at Intersections /Mid-block

Preferred Format

The statistics in Figure 10 show the overall display preferences for survey respondents, both in total and by their usage characteristics. The survey results show that 45 percent of the respondents liked Map C best, the format showing traffic levels for each direction along roadways. Map B, which showed traffic levels for each approach at an intersection using an arrow, was a distant second (23 percent). The least preferred option was Map A, the layout showing traffic levels for an entire intersection, regardless of the direction of traffic (7 percent).

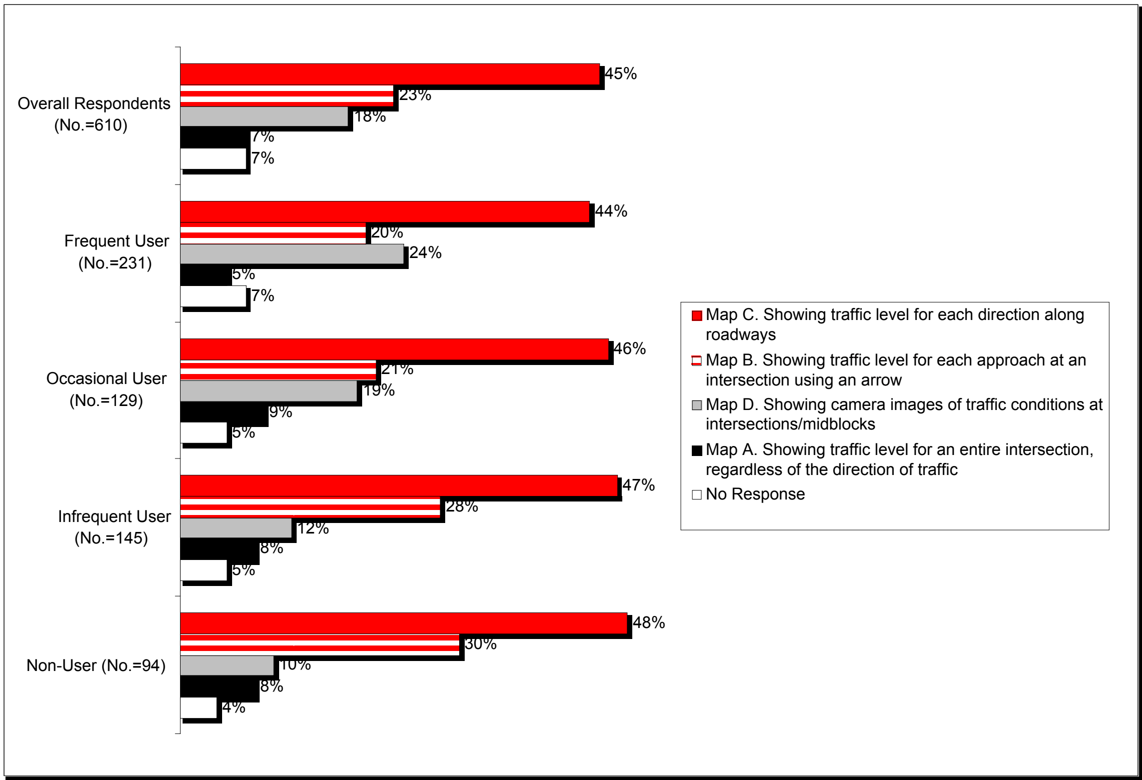

Figure 10. Preference for Display Format

While the response pattern among various groups, from frequent user to non-user, was generally similar (i.e., Map C was preferred by nearly half of respondents in each group, and Map A was the least preferred format), it is interesting to note how responses varied for Map B and Map D among different groups. The results suggest that a traveler who does not frequently access traffic information on the Web is more likely to prefer the format using an arrow to show traffic level for each approach at an intersection, while a frequent user finds camera images of traffic conditions more useful. As Figure 10 shows, infrequent and non-users were more likely to prefer the format using arrows to show traffic levels for each approach (Map B) than frequent and occasional users. Getting camera images of traffic conditions was rated more highly by frequent users than by the other groups. This suggests that it is initially more difficult for users to obtain the information they seek from cameras, but that after they become familiar with these images, cameras provide benefits not available through the map display. (However, note that the map displays were still preferred at more than a 3:1 margin over the camera images, even by frequent users.)

Figure 11 shows that although twice as many respondents chose Map C than chose Map B as their preferred display type, respondents rated the two maps similarly. Although both displays provide the same basic directional information, apparently the broad, colored road segment in Map C gives a slightly better visual clue for fast, at-a-glance, pre-trip route evaluation. In contrast, respondents felt that Map B, the format showing traffic levels for each approach at an intersection using an arrow, may be overly detailed. In their survey comments, respondents noted that although having detailed information about each approach is beneficial, knowing only the approach to key intersections, without information about the rest of the roadway, requires more time to evaluate the information presented.

As for Map A, which showed traffic levels for an entire intersection regardless of the direction of traffic, although it was the cleanest and easiest to read among the choices provided in the survey, fewer (only 12 percent) respondents thought it would be very useful. People preferred to get more detailed information. Respondents also commented about the phyical design of this display. Survey users had difficulty in distinguishing between the colors in this format because the resolution of the mock-up graphics used for this survey was too low, given the size of the colored area. This reinforces the basic design goal of making the graphic visually clear, with strong color contrasts.

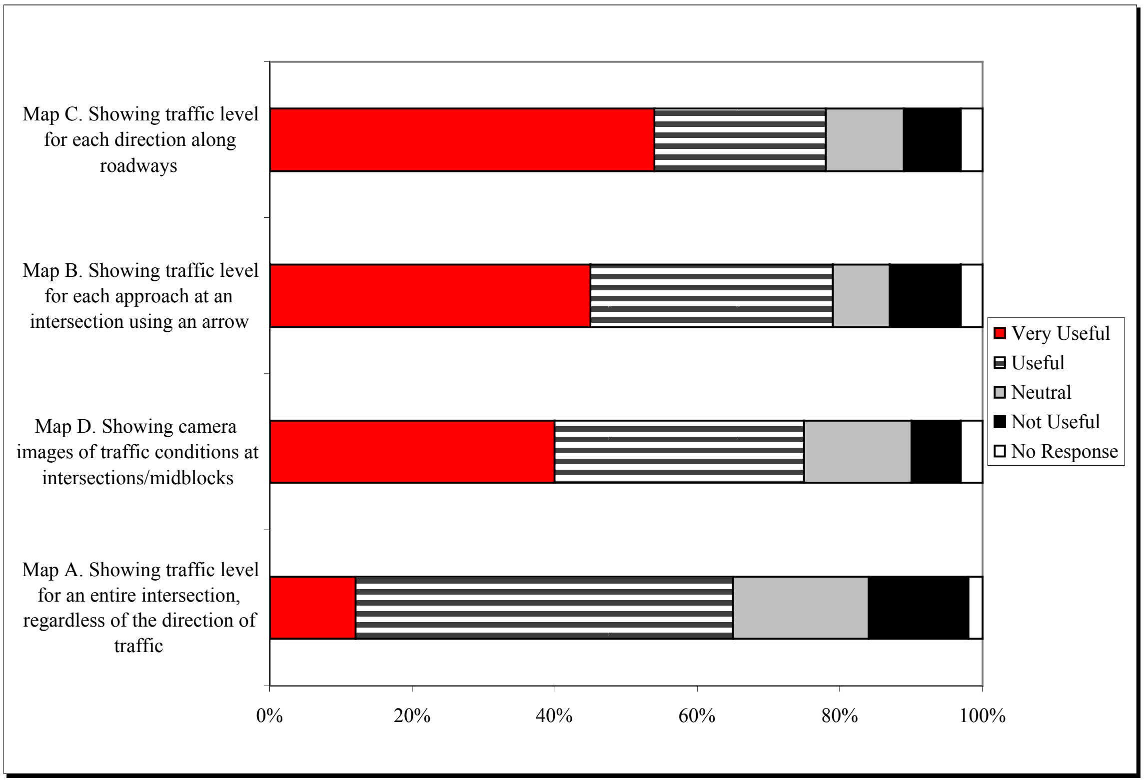

Figure 11. Ratings on Display Formats

While many respondents commented that they liked the ability to actually see what was going on in the area via camera views (see Figure 9), relatively few users would prefer to use them exclusively (18 percent). This observation may be due in part to several factors. First, photo images tend to be fairly large computer files, and consequently, extra time may be needed by the user to download camera views because more bandwidth is required to move the image from the server to the user's computer. This means that the camera views may be too slow to be helpful. In addition, the user must often examine more than one camera image to understand traffic conditions along the entire trip. One picture cannot show the condition of an entire route, as each camera image normally presents conditions at only one direction at one intersection. Finally, single frame still photos can be difficult to understand (e.g., does the image show real congestion or just cars waiting at a light?) and orient for those unfamiliar with what they see. The alternative, streaming video, requires even more bandwidth to deliver via the Internet, significantly increasing image download time, while still covering a single direction of traffic at a single intersection.

However, although most users did not think camera snapshots would be the most useful as the only visual display, camera views were generally thought to be beneficial in providing supplementary information. In fact, many users suggested combining camera images with other options such as the roadway segment and entire intersection options. Respondents thought that it would be useful to combine the colored map with camera images along that route, similar to the way the current WSDOT Traffic Condition Web site is designed. Survey responses indicate that a typical behavior with the current WSDOT FLOW map site is to get an overview of traffic conditions from the colored flow map, and then examine a few camera views to obtain details about the extent of the problem at key locations. This same approach appears to be desired for arterial information.

MAJOR FINDINGS

Analysis of the results of the Web-based user survey suggests the following:

- Knowing the location of traffic accidents seems to be more valuable to travelers than the other measures listed in this survey. When travelers plan a trip, warnings of incidents, construction activity, and special event traffic, as well as descriptions of possible alternative routes, can be useful supplements to typical traffic measures that describe current conditions.

- Users' indicated that with an appropriate level of detail, clear visual presentation, and adequate geographic coverage, the Web via desktop or laptop computers can be an effective medium for providing travelers with traffic condition reports for a specific location/segment. Radio traffic reports are useful for in-route travelers; however, the usefulness of this medium in providing traffic condition information can be enhanced by more frequent reporting.

- If real-time traffic information is available, the majority of travelers prefer that the information be presented in the form of actual, current conditions (e.g., heavy, moderate, or light), rather than as deviations from expected norms.

- While real-time traffic information provides travelers with an understanding of "what's going on right now" on the roadway, historical traffic pattern information (e.g., by time of day, day of week, time of year) can be a useful tool in helping travelers predict the best times or routes to travel.

- The preferred format and level of detail is a display of traffic conditions for each direction and along the entire roadway segment for quick, at-a-glance impressions of general traffic conditions.

- The display mechanism selected needs to balance detail and ease of use. For example, although a graphic of the average traffic conditions for an entire intersection was the cleanest and easiest format to read among the choices provided in the survey, it did not provide users with an adequate level of detail. In contrast, users preferred the level of detail apparent when traffic conditions are shown for each direction and along the entire roadway.

- Colors used in graphics should be easy to distinguish, and the graphics should be efficient to download to increase ease of use.

- The option of using camera images may seem more useful for those who frequently access Web traffic information than for those who rarely or never use it.

- Users considered camera views helpful for verifying conditions, and they also looked for camera images to provide more detailed information on conditions at specific locations of importance. Users generally prefer to get an overview from color-coded maps and then examine a few key spots with the camera views if additional information is desired.

CHAPTER 4
LOCAL PERSPECTIVES

To facilitate a more complete understanding of the current status of monitoring and reporting traffic information, a number of transportation agencies in the greater Puget Sound region were contacted to learn about their practices and to obtain their perspectives about future enhancements to arterial traffic monitoring. The transportation agencies interviewed for this study included the following:

Large-Sized (Pop > 100,000)	Medium-Sized (Pop < 100,000)	Small-Sized (Pop < 22,000)
WSDOT	Everett	Tukwila
King County	Kirkland	Woodinville
Seattle	Redmond	Issaquah
Bellevue	Lynnwood	

A list of people contacted through this project is provided in Appendix B. This chapter summarizes the findings from those interviews.

TRAFFIC CONTROL AND MONITORING

The common goal for all agencies contacted for this study is to optimize signal timing at intersections on the basis of normal, daily user demand and community concerns, as well as to operate special timing plans during construction and special events. Roadway management focuses on meeting critical capacity needs and improving safety, as well as on providing inputs to the land-use planning process, specifically, for how proposed land-use changes will affect traffic congestion and overall mobility.

Large cities usually have the ability to operate and maintain their own signals. Signal operation and/or maintenance in smaller cities is generally contracted to bigger cities or the county. For example, in addition to some 150 county traffic signals that King County DOT is responsible for, it is also under contract to operate and/or maintain another 250 signals for cities such as Shoreline, Woodinville, Kenmore, Tukwila, SeaTac, Issaquah, Federal Way, Burien, and Mercer Island.

Although many jurisdictions are interested in innovatively improving current operations and expanding infrastructure coverage, the level of effort dedicated to these projects depends largely upon the availability of staff and funding resources. Most agencies do not have enough resources or staff for real-time monitoring (hands-on observation and control) of arterial traffic flow. Smaller jurisdictions are particularly constrained and tend to look to ITS solutions primarily as a lower cost means of addressing significant community concerns, but even then, only when the ITS solutions require limited staffing. In this climate, collecting arterial operations data in real time is often of secondary importance. Thus, incident detection information on arterials is rarely collected by arterial management agencies, and only the larger, more sophisticated agencies collect real-time arterial performance information. However, as congestion increases and political pressure increases to more efficiently operate the existing infrastructure, more agencies will look to collect and distribute arterial performance information.

Real-Time Traffic Monitoring

Real-time monitoring of arterial traffic is not common in the Puget Sound region because of a combination of factors. Primary among these factors are the following:

- the lack of existing automated surveillance equipment on many arterials
- the lack of data collection capability within the intersection controllers currently operating many traffic signal networks
- the lack of communications capability and/or sufficient communications bandwidth within existing traffic signal control systems
- insufficient technical knowledge about how to convert available data into easily accessible public information
- insufficient financial and staffing resources to remedy the above conditions.

While some agencies (e.g., Seattle and Bellevue) can and do collect dynamic, second-by-second data for varying numbers of intersections and display them at their central control centers, other agencies can only call up signal controllers and download data on a periodic basis, such as when data are being collected to develop new timing plans. Or they can not collect or access data remotely at all. Real-time data (usually volumes and lane occupancies) are routinely collected by local traffic signal controllers running timing plans that use signal actuation, but these data are not routinely transferred to a central location where they could be accumulated, summarized, and distributed as traveler information.

No city in the metropolitan area is currently using true adaptive traffic signal control (e.g., SCAT or SCOOT). The City of Bellevue does operate a signal system that responds to current traffic conditions by selecting between alternative, stored traffic signal control plans on the basis of current traffic patterns. This is accomplished by matching measured volumes and occupancies against stored volume and occupancy profiles. However, the majority of the agencies surveyed do not utilize this capability because of a lack of resources to fund the extensive data collection process necessary to operate such a system.

Many of the agencies interviewed, however, are interested in developing more extensive traffic monitoring capabilities. In most cases, these improvements are designed to help address significant arterial congestion problems, where traffic volumes are both high and highly variable, making traditional traffic signal control plans both inefficient and expensive to maintain without more robust traffic control and surveillance capabilities.

Sensor Coverage

Infrastructure is needed to support the data collection necessary to provide real-time monitoring. Agencies want to expand the use of detectors and apply more ITS technology (which is currently not included in city budgets or comprehensive plans) to provide speed and congestion measures for arterial streets. Traditionally, detectors are primarily used for operating actuated and semi-actuated signals. In most cases, sensor coverage is limited; not every signalized intersection approach is equipped with detectors, and relatively few mid-block detectors are installed. In general, the newer the signal control system, the more extensive and robust the detection system. The older the signal control system, the less extensive the surveillance.

The placement and design of data collection sensors is dictated by traffic flow characteristics and the type of signal control used at an intersection, whether pre-timed, semi-actuated, or fully actuated. For some arterial signal control applications, data collection is not necessary. Even within a single jurisdiction/agency, traffic data are often not uniformly available at all intersections. For example, the city of Seattle runs some fully actuated signals, but a large number of its arterials are semi-actuated, with no detection placed on the through-lanes of the primary arterial movement.

Even when detection is available, the design (location and shape) of the sensors themselves can provide very different data from one location to another. Traditional inductance loop detection at an intersection can vary from simple square loops (one per lane) to rectangular loops (6 ft by 40 or 50 ft). Detector installations are designed to meet specific signal control needs (vehicle detection, dilemma zone coverage, vehicle volume counts, speed measurements) and may not provide the data desired. (For example, a 6-ft by 50-ft rectangular loop placed upstream of an intersection can provide excellent vehicle presence detection and dilemma zone coverage, but tends to do a poor job of counting vehicle volumes.)

Lastly, the signal control hardware must be capable of collecting, storing, and reporting detector data. Some control systems, particularly older ones, allow only a limited number of detectors to report data centrally. These constraints are usually the result of limited data processing or communications capabilities within the control hardware.

Agencies interested in replacing old signal control hardware, or purchasing control hardware for new arterials, should consider not only the direct operational functionality of the traffic signal system they are building, but the potential for centrally collecting and using traffic surveillance information required by intersection controllers. This may require some additional communications capabilities, but it can provide for significant improvements in traffic management and makes possible dissemination of arterial performance information to the public at relatively little additional cost.

Surveillance Technology

The interviews revealed that inductance loops are most commonly used in the Puget Sound region to count vehicle volumes and detect vehicle presence and/or lane occupancies (the time that the loop is occupied by a vehicle) for signal control operations, although video image detection is becoming more popular. Some agencies wish to move away from conventional inductance loops to video detection because video detectors are more flexible. In particular, video detectors allow easier adjustment of detection locations in response to changing roadway conditions caused by construction events or changes in channelization at intersections. For example, both the City of Lynnwood and the City of Bothell selected video image detection when they upgraded their primary traffic signal networks. Lynnwood now operates 30 video detectors and is in the process of adding 100 more.

In Woodinville, the next step in video detection is being considered. In traditional video detection (such as with Autoscope™ cameras), the video image is not transmitted from the detector. Instead, the camera image is converted on-site to detector outputs (volume, speed, lane occupancy), and that information is transmitted from the site. Some newer video systems allow the camera to operate both as a detector and as a CCTV camera. These detectors require higher bandwidth communications (because they must transmit video images, not just summary statistics), but they allow a single camera to perform two different functions. One such video system is planned for the intersection of Woodinville-Duval Road and Paradise Lake Road to monitor both traffic conditions and the flooding conditions that can occur at that key intersection. The benefits and costs from this arrangement are not well quantified at this time.

Most agencies interviewed think loops are maintenance intensive but otherwise reliable. The cost of loops (not including conduit work) and conventional video detectors are comparable. Typically, loops cost $400 to $1000 a piece, depending on the quantity required and the expense involved in wiring the intersection. Installation generally costs significantly more than the equipment itself, and the cost increases substantially if significant installation of conduit is required. Video detection costs roughly $3500 to install four cameras that can monitor up to four lanes per camera. Similarly, these costs can increase significantly if additional conduit is needed or if no locations for mounting cameras are readily available. (This is rarely a problem at intersections because light standards can be used, but it can be a problem for surveillance locations that are not at signalized intersections.) Because site characteristics significantly affect equipment cost and performance, selecting between loop and video detectors is often driven by the attributes of the location being instrumented.

The other popular surveillance tool commonly used in the Puget Sound region is the CCTV camera. Great interest was expressed in implementing CCTV cameras at signalized intersections to help verify traffic conditions on arterial streets and to aid transportation operator decision-making. CCTV cameras help operators determine whether unusual conditions are caused by “normal” traffic, special events, or incidents. CCTV cameras can also be used to monitor the performance along longer corridors and can provide information on the volume and performance of non-motorized modes.

In Bellevue, operators utilize their CCTV cameras to visually verify the performance of the traffic responsive patterns, inspect the before-and-after impact of new timing plan implementations, identify whether a selected plan is working (to modify that timing pattern in real time if it is not working correctly), and observe the traffic patterns that occur as a result of specific events, to provide insight into the design of future signal control plans.

Communications Capability

Communications are vital for obtaining real-time data. Often, a key constraint to obtaining real-time arterial performance data is the lack of communications capability within an existing traffic signal control system. Limitations in communications capability can occur either because the communications lines are insufficient to support the desired level of communications, or because the traffic control hardware is not designed to provide the level of communications desired.

A central computer that links to all intersections with frequent updates of traffic conditions (on the order of an update every few minutes, at the slowest) provides the type of real-time information desired for arterial advanced traveler information system (ATIS) services. However, even this level of communications is only useful if the central computer is capable of communicating those data to external sources, for example, a server that can draw and publish an ATIS flow map on the Internet. (Slower communication rates can still be used for providing effective ATIS services.) Central control of signal timing requires more frequent communications, on the order of every second. While this level of communications allows the most robust traffic management activity, arterial performance updates that occur at least once per signal cycle are usually sufficient for most supervisory arterial management functions.

Few local jurisdictions use second-by-second communications to a central computer. Most smaller cities operate traffic signal systems that use more distributed traffic control (i.e., where most control decisions are made by on-street traffic control equipment) but that also permit much more limited central control functions. Under traditional distributed signal control architectures, data collected by detectors for actuated signal control are available only at the local controllers or on-street masters. Communications to these devices are most commonly performed only periodically, either via dial-up telephone connections or by a physical visit to the signal control cabinet to download the desired data. Many older signal control systems are simply not designed to store and report the intersection performance data needed for traveler information services.

Use of Traffic Data

Most cities collect and analyze data such as volume and occupancy to

- develop efficient timing plan changes for normally recurring traffic flows
- conduct analyses for future planning
- select appropriate synchronization plans for current traffic conditions (e.g., to be traffic responsive)
- detect technical equipment failures
- address citizen complaints.

The ability to collect these data from existing traffic control systems is a function of the location, design, and number of detectors installed. Where these data can not be collected by the existing signal control detectors, they must be collected either manually or by detectors placed specifically to collect information. This latter case is rare but might be done specifically to meet traffic monitoring requirements for a key facility.

The availability of traffic volume and performance data from traffic signal control system detectors varies dramatically from city to city, and even among signal networks within a city. The availability of volume and performance information from signal control systems is a function of detector design (e.g., square versus rectangular detection zones), detector location (e.g., stop bar, intersection approach, or mid-block), and signal controller capabilities (data storage and communications capabilities).

Some cities (e.g., Bellevue) make extensive use of their traffic signal system for collecting routine data for planning, operations, and design purposes, while others can collect little data in this manner. In all cases, this is a function of the age and design of the traffic signal control system being used. Most staff interviewed consider automated data collection from traffic signal systems a very good idea, but some expressed concerns about their ability to manage the flow of data from such systems.

Several persons interviewed pointed out that detector placement, data storage capabilities, and communications capabilities need to be considered as part of the selection and design of signal control systems. And even when data collection and traffic monitoring are considered, they are not always implemented as desired because of financial constraints on the agency.

REPORTING ARTERIAL TRAFFIC INFORMATION

Most cities that were interviewed are not actively gathering and using real-time traffic data. Consequently, those data are not readily available to travelers. The only traffic data commonly available to the public tends to be historical traffic volume data, which can be obtained in the form of written reports and printed flow maps. For example, in Tukwila, a hard copy of a flow map published in the comprehensive plan shows volume counts on major roads.

Currently only two Puget Sound jurisdictions provide arterial performance information on the Internet. Both Seattle and Bellevue provide CCTV snapshots of real-time arterial/intersection traffic conditions for selected intersections through their Web sites. Three CCTV cameras have been strategically positioned in Seattle (including both intersection and mid-block views) near the I-90 touch down, Royal Brougham Way, and Colman Dock to monitor traffic conditions during special events. In Bellevue, CCTV cameras have been located at twelve intersections. In all cases, the Web snapshot shows traffic conditions in one direction at a time (e.g., facing north), with the view controlled by the city engineering staff. Both cities have had positive feedback from the public about providing real-time CCTV snapshots. Both cities are planning to implement additional cameras at critical locations. In the meantime, other cities are also looking into installing CCTV.

Interviews performed for this project indicated that most smaller agencies are not strongly interested in providing arterial information to the public. These agencies tend to believe that arterial traffic and incident information would not be useful and is, therefore, not worth the cost. This appears to be the case primarily because no alternative routes for routine congestion exist, or because congestion dissipates quickly. Larger jurisdictions, and those smaller jurisdictions with alternative travel paths, do share an interest in making real-time data graphically available to the public. For example, the City of Lynnwood is planning to share camera images with WSDOT and will possibly post those images on WSDOT's Web site in a manner similar to Seattle and Bellevue. King County is investigating what technology to use and how to convert arterial data to a useful format for public dissemination as part of a project for NE 124th Street near Totem Lake. The

City of Woodinville is considering placing a flow map on the Internet, as well as placing real-time VMS signs before junctions that lead to by-passes around its congested downtown.

Despite mixed comments on the current plans from different jurisdictions, a number of interviewed staff expressed a strong desire to produce color-coded, arterial performance flow maps on the Internet. However, since this appears to be a difficult and perhaps costly endeavor in the immediate future (i.e., until traffic signal control systems are upgraded to provide the appropriate data in an easily obtained format), the most common ATIS improvement planned is to install one or more CCTV cameras at key locations within the jurisdiction. While limited CCTV cameras do not provide the breadth of coverage provided by a flow map, individual cameras can be purchased, installed and brought on-line quickly and at modest expense. This allows cities to provide modest ATIS improvements to their citizens without major expense to the city.

CHAPTER 5
CONCLUSIONS AND IMPLEMENTATION RECOMMENDATIONS

This study arose from the need to understand ways to collect and present real-time arterial congestion information to the public. Emphasis was placed on using data generated from existing surveillance systems and the Internet as the primary dissemination medium. However, agencies that had no available data sources expressed interest in obtaining guidelines for making improvements that would help them provide real-time arterial performance information to the public.

CONCLUSIONS

The results of the study confirmed that jurisdictions have a high level of interest in obtaining arterial traffic condition information for both arterial management and public information purposes. However, existing sensor coverage and equipment capabilities, as well as the manner in which data are (or are not) captured, require that much work be done before existing data sources can supply traffic data to Internet-based display systems. The recommendations presented later in this chapter identify the steps agencies will need to follow to present arterial traffic data to the public.

The "easiest" approach to modestly improving the availability of arterial performance information appears to be the installation of Internet ready CCTV cameras. Real-time video images can be an effective tool for verifying traffic conditions and managing incidents at important intersections or arterial segments. Data captured by CCTV cameras can be displayed in full motion with high bandwidth or as still-frame images with low bandwidth. Although this project's survey indicated that camera images are not users' "preferred" method for receiving arterial performance information via the Internet, the public does appreciate these images, and the cameras do provide useful traffic management information to the agencies that install them. They are also much less costly than the systems needed to provide data for the public's preferred display mechanism (a fully color-coded map display). Hardware and installation costs for a CCTV camera run from $10,000 to $50,000 per location, depending on the type of camera installed, the availability of power and communications connections, and the site's geometry.

The "best" option appears to be a combination of both CCTV and flow maps, and placement of CCTV before the development of flow maps does not detract from that eventual system. The public's favorite option requires a much more comprehensive data collection process and a more sophisticated data preparation effort than does CCTV. Such an approach is well worth pursuing because it provides arterial information over a wider area and is therefore more valuable for both public information and arterial management. However, most arterial control systems are not currently designed to allow significant changes in the data that are collected and displayed for either traffic management or public information purposes. Whether these changes can be made to existing systems, and what those changes would be, varies significantly among control systems. In many cases, these functions are beyond the capabilities of existing control hardware, and therefore, these improvements must wait until signal control systems are upgraded for other reasons. In the meantime, agencies can still undertake more modest efforts toward improved arterial performance data collection; a lack of resources should not prohibit an agency from taking progressive steps toward better arterial information.

RECOMMENDED ACTIONS

Recommended actions for agencies that are responsible for arterials and want to provide arterial information to the public are summarized in the steps below. These steps are illustrated in Figure 12. (Note that while these steps are somewhat linear, there is considerable feedback between steps. For example, the availability of information has considerable impact on what information is provided to the public.)

- Step 1. Assess where traffic condition information is most needed by the public and/or operating agencies.
- Step 2. Determine whether data collection capabilities already exist at those locations, and if so, how the data collection occurs.
- Step 3. For locations that have existing data collection capabilities, determine how (or if) those data can be cost effectively captured for use in external applications such as Internet display software. Similarly, for locations that do not have, or have insufficient, data collection capabilities, determine how the required traffic condition information can be most cost effectively collected.
- Step 4. Determine how to convert the available sensor data into the desired information for presentation.
- Step 5. Determine the media that can best be used to provide that information to the public and/or operations staff.
- Step 6. Install, test, and operate the infrastructure needed to present information to the intended audience.

Each of these steps is discussed below.

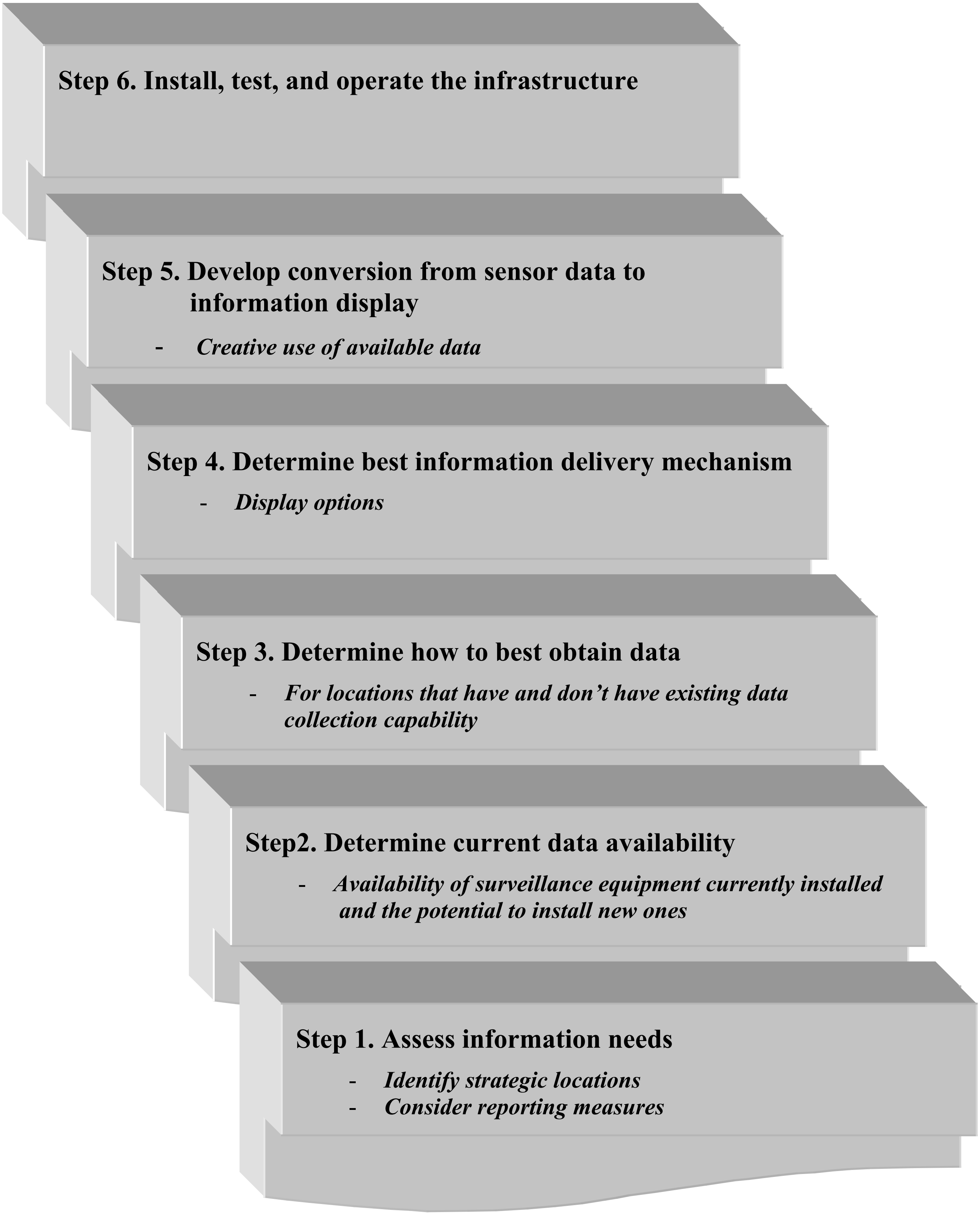

Figure 12. Key Steps for Providing Arterial Performance Information

Step 1. Assess Information Needs

The first step is to assess from which locations (corridors, segments, intersections) traffic condition information should be reported to meet the community's needs and/or to provide operational control benefits. This step will target the data collection and reporting efforts to the most critical and useful locations. Prioritizing and focusing on these strategic locations will enhance the agency's ability to improve motorist information with a smaller number of detectors, which in turn will reduce communications and maintenance costs.

The results from the Web survey performed for this project clearly indicated that the public is interested in corridor-wide information but is happy to receive any arterial information. For traffic management purposes, agencies may be interested in common bottlenecks or trouble spots, or they may be interested in information on network operations as a whole.

Where resources are limited and information is not readily available (see steps 2 and 3 below) most agencies attempt to collect data at key intersections that tend to control or influence the performance of entire corridors or networks. Candidate data collection locations are normally associated with "well known problem locations" within a city, locations that accurately describe the relative merits of alternative routes around known congestion points, or locations that serve as indicators to control system personnel attempting to adjust traffic management system operation. The selection of key locations is a function of the needs and priorities of the agency involved. Examples of these key locations include the following:

- arterial streets connecting to freeway ramps

- arterial streets that serve as alternative routes to a freeway or other regional roadway
- key locations along a highway that cuts through a city
- key congestion locations near special event facilities, such as roads around major shopping malls or recreational facilities
- key intersections within a central city core
- railroad crossings of arterials that do not have grade separation.

Part of this task also involves considering the type of information the agency wants to provide (e.g., camera images, color-coded map, text reporting) and the alternative reporting mechanisms (e.g., Web-based, VMS) that can be used to provide that information. The choice of the appropriate medium tends to be driven by which type of data can be most easily obtained.

Step 2. Determine Current Data Availability

The second step is to review the availability of installed surveillance equipment and the potential to easily install new surveillance equipment. When looking at current surveillance capabilities, the agency needs to determine

- where detectors are currently located (which intersections have detection and which approach legs are covered by that detection)
- what types of detectors are present (loops, video loops, CCTV, other)
- whether those data are currently reported to a central location
- what data (measurement units) are actually reported (volume, speed, lane occupancy, still video image, full motion video image, other)
- the time frame during which these data are updated (frequency of data reporting)
- the type, speed, and reliability of the communications links that support this data collection effort

- whether data currently available at the intersection (but not currently reported centrally) can be collected centrally, given minor improvements in signal control hardware or software (e.g., if a modem and phone line were added, or if an additional software script was written for the on-street master controller).

These existing data sources should then be mapped against the needs identified in the first step. This data map should include notations about data sources that could be obtained with only minor changes in existing hardware and software.

Finally, it is important to realize that a variety of data can be used for performance monitoring. For example, all three types of common detector outputs (volume, lane occupancy, speed) can be used to determine facility performance. Thus, if one of these data items can be collected but not the others, an agency should consider whether the data that are available can be used to report arterial/intersection performance, even if they are not the preferred measurement statistic.

Step 3. Determine How to Best Obtain Data

Given the knowledge of what data currently exist and whether they are readily accessible, it is possible to develop a plan for meeting the data needs of the desired arterial information system and to determine whether collecting the data desired is fiscally possible. The data collection plan should include both actions needed to extract currently collected data and any new data collection installations required to fill gaps in the current surveillance system. These two basic elements are discussed below.

If traffic detection already exists at the desired locations, the next step is to determine how to extract that information from the current data collection system so that it can be used for additional purposes. This may or may not be a simple matter, and it requires technical knowledge of the specific control system being used. In some systems, data can be readily exported in real- or near-real-time by simply designating the data collection locations to be reported. In other systems, data are transmitted and retained only within proprietary control algorithms and are not readily exported. However, even in proprietary signal systems, minor software modifications (e.g., writing new software scripts) may be possible to enable the necessary data storage and communications functions. An agency may also have to add or upgrade communications links to allow data currently collected in the field to be transmitted to a central location. In some cases, however, the current hardware may not be able to perform the functions required.

At the end of this task, the arterial agency should be able to identify the data that can be readily obtained from existing systems and the costs of and tasks required for extracting those data.

Where the existing surveillance data can not be readily exported or where the costs for exporting these data are too high, the arterial agency must explore the possibility of installing new surveillance hardware. The advantage of placing new equipment is that it can be specifically designed to provide the desired data, whereas use of existing detection equipment limits the data available to meet some other purpose. For example, although data collected by loops located at an intersection's stop bar may obtained and used, those data are not as descriptive of traffic delay at the intersection than data collected from either a set of advanced queue loops or a video camera placed to observe queue size.

In the Puget Sound region, surveillance systems are dominated by three technologies: inductance loops, video detection, and CCTV. However, a number of other technologies on the market can provide this type of information.[5] [6] [7] Each technology has strengths and weaknesses in terms of type of data collected, locations where the equipment works well, cost, accuracy, and reliability. Most of these technologies produce the same basic measures as loops, i.e., volume, speed, and lane occupancy. Agencies should select the technologies that provide the best balance between meeting their data collection needs and fitting within their operational constraints.

The cost of new surveillance equipment may be so high that an agency can not afford to collect the data identified in the first step of this process. This usually means that the arterial monitoring plans must be revised. A common change in plans is for agencies to move from flow map displays to simple CCTV images. Even on a small budget, a limited number of CCTV cameras linked to the Web can be installed, and the benefits from those cameras generally outweigh their costs.

In such a case, corridor-wide flow map displays might be delayed until other factors require an upgrade to traffic control hardware that can more cost effectively collect corridor-wide data. At that time, the arterial will have the level of coverage preferred by many survey respondents: a flow map for quick review, with CCTV camera images available for more detailed analysis as needed.

Step 4. Determine Best Information Delivery Mechanism

Once an agency knows what data will be available, it can both refine the information delivery mechanism and define the units of measure that will be used to create the information display. If the decision is to provide CCTV images to the public, this normally means the design of a map-based Web site, with camera locations clearly indicated. Such a map should be linked to other existing Web-based traveler information sites for the metropolitan area, particularly those maintained by the state DOT.

Similarly, arterial flow maps are an excellent display possibility if the data exist to create them. Examples of such displays are currently operated in Detroit and San Jose. Links to such a site should also be constructed to and from the DOT's freeway performance Web site.

Internet displays may not be the best or only information delivery mechanism required. Particularly if the primary goal of the arterial monitoring effort is traffic management, other information dissemination systems may provide the functionality desired. For example, a VMS sign before a road junction may be a far more effective traffic management display than a Web site. Traffic condition information extracted from a signal system may not need to be placed into Web format to control such a sign. Instead, a simpler display system operated exclusively from the central traffic office might provide all of the data needed for manual control of the VMS.

The key, at this point in the design process, is that the agency should be able to determine what data will exist and how to best format and disseminate those data to meet the stated objectives.

Step 5. Develop Conversion from Sensor Data to Information Display

The next task is to develop the methodology for interpreting the available traffic data from various detectors and detector locations to produce the displays decided upon in step 4.

This is a simple task if the output is a video image. However, if the primary display mechanism is an Internet flow map, the agency must determine how the collected data will be used to color code that map. WSDOT currently maintains an excellent example of an on-line flow map for its freeway system. This map converts measures of lane occupancy into color-coded map segments. Each segment is assigned to a specific loop or group of loop detectors, and WSDOT defines the conversion from loop occupancy measure to roadway segment color (that is, at what lane occupancy level the map segment color changes, from yellow to red for example).

This task becomes more difficult if the data collected are not consistent from site to site. This occurs frequently on arterials. One reason might be loops placed at different locations at each intersection. Similarly, different loop designs (e.g., square loops at some intersections versus rectangular loops at others) might require slightly different conversion statistics.

Because few arterial performance map displays exist, there is no clear standard for converting arterial performance measures to map images. The process is made more difficult because a number of measurement units, including vehicle volumes, vehicle speeds, lane occupancy percentages, and even levels of saturation, can be used to color code map segments. Consequently, the conversion of surveillance measurements into map displays may require some trial and error.

Some guidance can be obtained from the limited number of arterial flow maps currently on the Web. Detroit produces map images from its traffic signal control system. Its display map provides only relative congestion terms (Heavy, Moderate, Light). These conditions appear to be determined on the basis of saturation flow levels for each approach to an intersection, which are produced by the city's SCAT signal control hardware and software. Detroit's map can be observed at http://www2.rcocweb.org/.

Users can select any of three arterial performance measures as the basis for color coding segments on San Jose's flow graphic. Segment performance can be based on volume, speed, or "level of congestion." The map image contains a key that allows a user to translate the map colors to specific volume and speed measures. No specific definition of "congestion" is provided, although it is likely to be based on lane occupancy. San Jose's map can be found at http://www.ci.san-jose.ca.us/traffic/sj_down_inv.html.

Step 6. Install, Test, and Operate the Infrastructure

The last step in the process is to create the system that has been designed in the previous steps. The actual system construction, installation, and testing may also result in changes to decisions made above. This is particularly true if anticipated data are not available or become available in an unexpected form or at an unexpected time.

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5 D. Middleton, D. Jasek, and R. Parker, Evaluation of the Existing Technologies for Vehicle Detection, Project Summary Report 1715-S, Texas Transportation Institute, September 1998.

6 Klein, Lawence, et. al., "A Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems," Produced by The Vehicle Detector Clearinghouse, New Mexico State University, for the Federal Highway Administration, U.S. Department of Transportation, Fall 2000, <http://www.nmsu.edu/~traffic/>

7 Thomas, G.B. "Optimal Detector Location on Arterial Streets for Advanced Traveler Information Systems," Doctoral Dissertation, Arizona State University, December 1998

APPENDICES

APPENDIX A
WEB SURVEY

Arterial Traffic Condition Information Survey

Washington State Department of Transportation

TRAC WASHINGTON STATE TRANSPORTATION CENTER

The Washington State Transportation Center at the University of Washington is conducting a public opinion survey to better understand how to supplement information about traffic conditions on major freeways with information about traffic flow on city streets or arterials. This survey should take no more than 5 minutes to complete. Your input is important in helping us develop on-line arterial traffic condition information. Please note that the information you provide will be kept strictly confidential.

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1. Have you ever used the City of Seattle and Bellevue camera snapshots available on the Web to get information about traffic conditions on city streets?

   [Select from pull down menu]

   If yes, how frequently do you use this information?

   [Select from pull down menu]

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2. How useful would it be for you to have the following on-line information about traffic flow on city streets?

   Camera snapshots of the roadway (a still photo of curent conditions)
   [Select from pull down menu]

   Full motion live video of the roadway [Select from pull down menu]

   Description of the level of congestion on the street [Select from pull down menu]

   Predicted travel time between two locations [Select from pull down menu]

Description of the speed of traffic on the street [Select from pull down menu]

Description of traffic volumes [Select from pull down menu]

Location of incidents [Select from pull down menu]

Other [ ] [Select from pull down menu]

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3. Please indicate how useful the following formats for delivering traffic information are to you.

The Web via desktop or laptop computers [Select from pull down menu]

The Web via handheld and palmtop devices [Select from pull down menu]

Telephone or cellular phones [Select from pull down menu]

Radio [Select from pull down menu]

Television [Select from pull down menu]

In-vehicle navigation devices [Select from pull down menu]

Kiosks [Select from pull down menu]

Pager [Select from pull down menu]

Other [ ] [Select from pull down menu]

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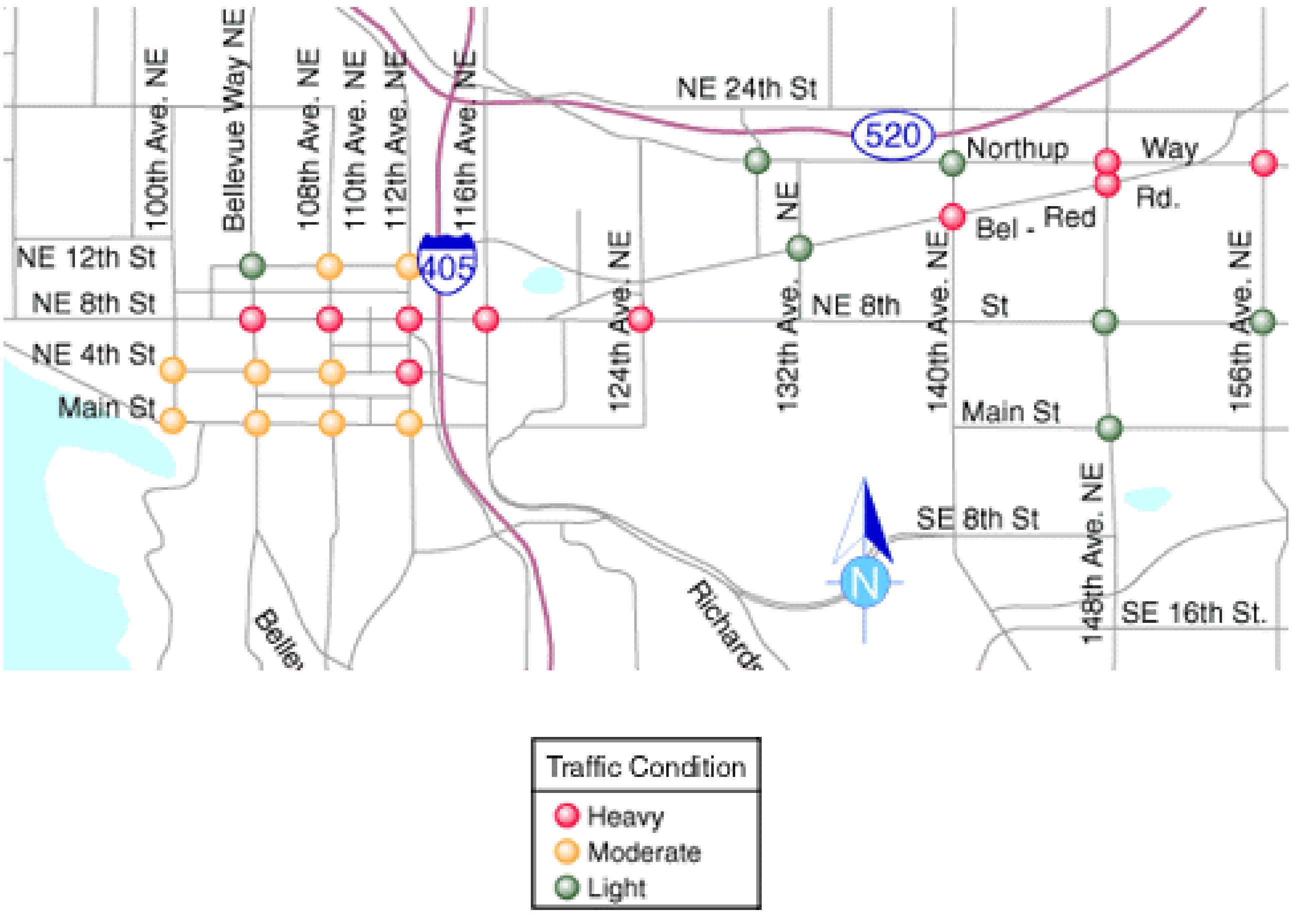
4. Which is more helpful to you: actual, current conditions for arterial streets (e.g., heavy, moderate, or light) or current conditions compared with average, historical conditions (e.g., typical or worse than usual)?

[Select from pull down menu]

5. Traffic information can be presented in different formats. Please indicate how useful the following display formats are to you.

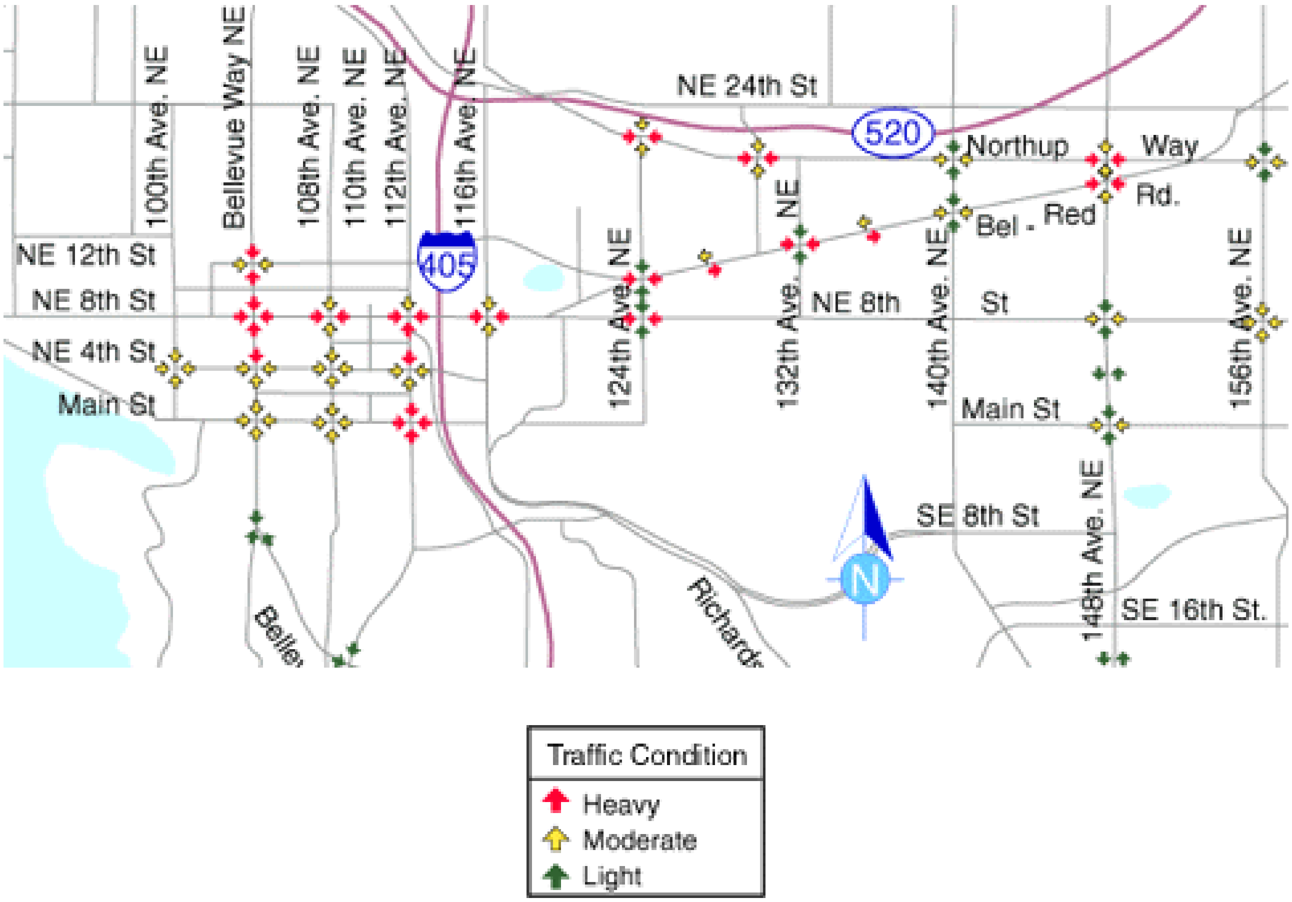
A. This figure shows traffic levels for an entire intersection, regardless of the direction of traffic (see circles).

This format is [Select from pull down menu] for making travel decisions.



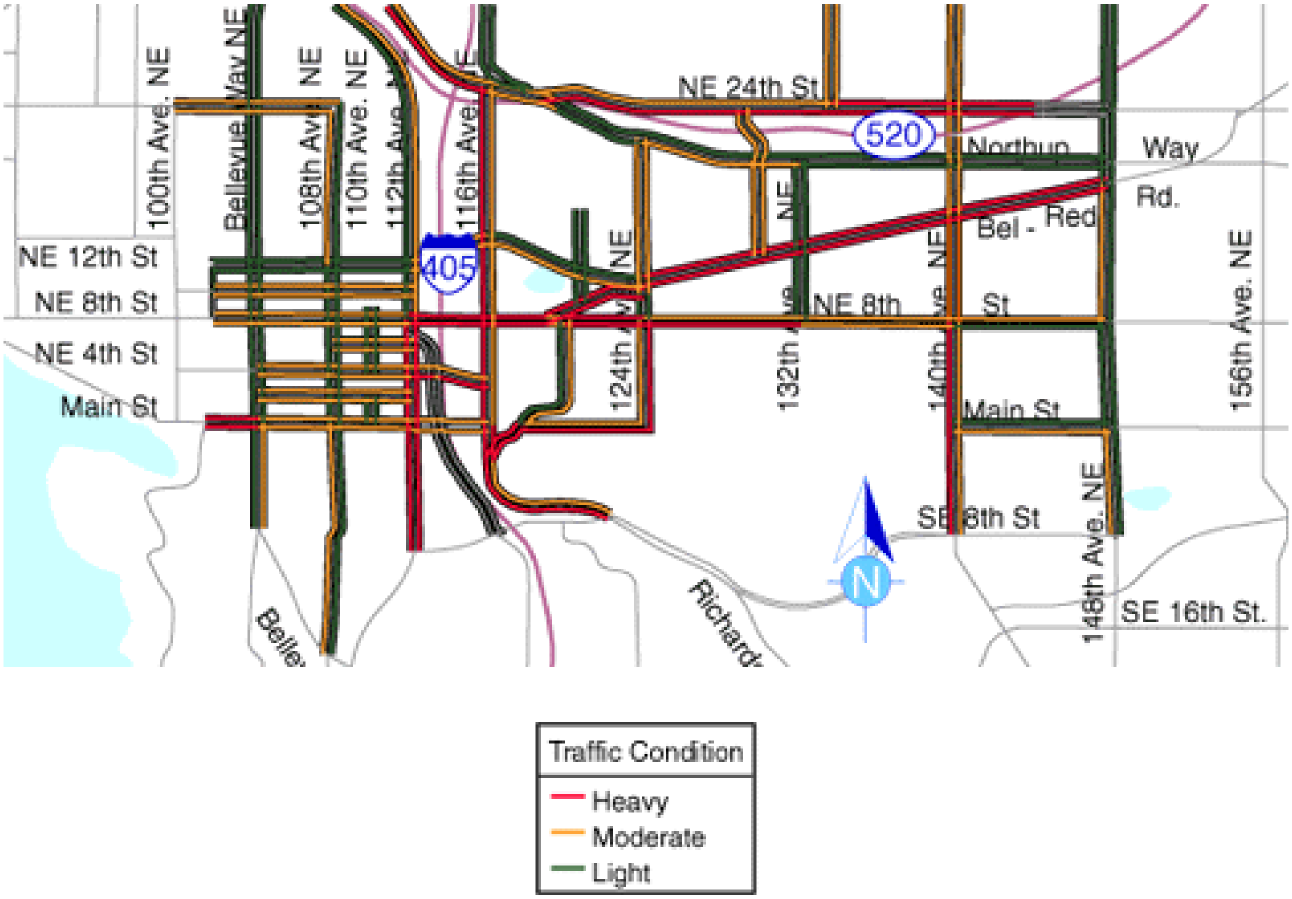
B. This figure shows traffic levels for each approach at an intersection, with traffic direction indicated by an arrow (see arrows).

This format is [Select from pull down menu] for making travel decisions.



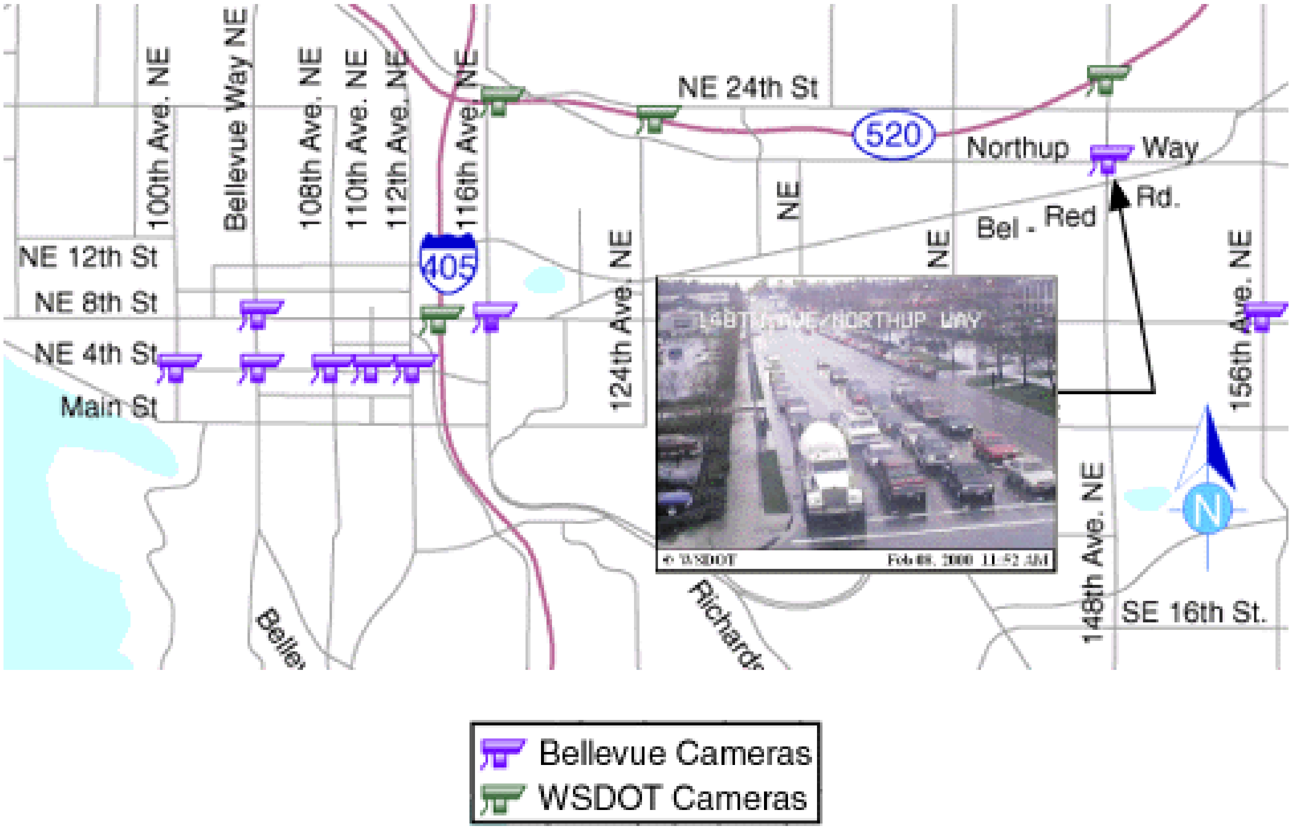
C. This figure shows traffic levels for each direction along the entire roadway (see bars).

This format is [Select from pull down menu] for making travel decisions.



D. This figure shows camera images of traffic conditions at intersections/midblocks.

This format is [Select from pull down menu] for making travel decisions.



E. Which of the display formats shown above do you prefer?

Select from pull down menu

---

6. Please provide your comments here:

Gender:	Select from pull down menu
Your Age:	Select from pull down menu
Education:	Select from pull down menu

submit or Clear Survey

Thank you for taking the time to complete this survey.

APPENDIX B
LOCAL AGENCY CONTACT LIST

Local Agencies Polled	Contact Name	Email Address Phone No.
WSDOT	*Ghadeer Baghai* *Transporation Engineer* *SC & DI Design*	*baghaig@wsdot.wa.gov* *(206) 296-8153* *mobile-(206) 940-6513*
King County	*Fred Housman* *Signal Supervisor*	*Fred.Housman@metrokc.gov* *(206) 296-8153* *mobile-(206) 940-6513*
Seattle	*Chuck Morrison* *Signal Operations Engineer*	*chuck.morrison@ci.seattle.us* *(206) 684-5122*
Bellevue	*Fred Liang* *Associate Traffic Signal Engineer*	*fliang@ci.bellevue.wa.us* *(425) 452-5361*
Everett	*Bill Saur* *Traffic Enginner*	*(425) 257-8800*
Kirkland	*Dave Godfrey* *Traffic Engineering Manager*	*dgodfrey@ci.kirkland.wa.us* *(425) 828-1214*
Redmond	*Paul Cho* *Traffic Operations Engineer*	*pcho@ci.redmon.wa.us* *(425) 556-2751*
Lynnwood	*Dick Adams* *Transportation Engineer*	*dadams@ci.lynnwood.wa.us* *(425) 670-6663*
Tukwila	*Brian Shelton* *Traffic Engineer*	*bshelton@ci.tukwila.wa.us* *(206) 433-0179*
Woodinville	*Joe Seet* *Traffic Engineer*	*joes@woodinville-city.com* *(425) 489-2700 x251*
Issaquah	*Sheldon Lynn* *City Engineer*	*sheldonl@ci.issaquah.wa.us* *(425) 837-3426*