Detector Data Validity

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16. ABSTRACT

The purposes of the research were to develop a data error detection algorithm and to recommend an improved database that will flag the errors detected by the new algorithm for the WSDOT's electronic surveillance system located at the Traffic Systems Management Center in Seattle. The algorithm compares 20-second volumes and 20-second volume/occupancy ratios with threshold values to determine the reliability of detector data. The algorithm will operate on the central computer system for the electronic surveillance data.

Tests of the algorithm proved it to be very successful at detecting data errors caused by short pulses (hanging off) from detectors, chattering detectors, and intermittent malfunctions of detectors. The algorithm did not detect errors caused by long pulses (hanging on) from detectors. The false alarm rate was very low (12 false alarms out of 3,510 observations).

The research team surveyed existing and potential users of the data collected by the electronic surveillance system. On the basis of the user responses, the research team developed a technique to flag erroneous data in the existing system, recommended flagging procedures for the new computer system being designed, and recommended a database configuration that will meet the needs of WSDOT and outside users.

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Final Report

Research Project GC 8286, Task 24
Detector Data Validity

DETECTOR DATA VALIDITY

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SUMMARY

This research project developed a data error detection algorithm for the Washington State Department of Transportation's electronic surveillance system, which is located at the Traffic Systems Management Center in Seattle. The algorithm compares 20-second volumes and 20-second volume/occupancy ratios with threshold values to determine the reliability of detector data. The algorithm will operate on the central computer system for the electronic surveillance system.

Tests of the algorithm proved it to be very successful at detecting data errors caused by short pulses (hanging off) from detectors, chattering detectors, and intermittent malfunctions of detectors. The algorithm did not detect errors caused by long pulses (hanging on) from detectors. The false alarm rate was very low (24 false alarms out of approximately 3,500 observations).

The research team surveyed existing and potential users of the data collected by the electronic surveillance system and reviewed the WSDOT's Data Rationalization Study and FHWA's Traffic Monitoring Guide. On the basis of the user responses and review of these two documents, the research team developed a technique to flag erroneous data in the existing system, recommended flagging procedures for the new computer system being designed, and recommended a configuration for the new database that will meet WSDOT's and outside users' needs.

The principal findings of this research were as follows:

(1) The data error detection algorithm developed as part of this project should be implemented on the TSMC computer system.

(2) Additional simulations should be undertaken to further substantiate the conclusions given.

(3) The thresholds used in the algorithm should be adjusted in order to calibrate the algorithm to the WSDOT system. (The current thresholds are

based on data collected in Ontario, Canada. These thresholds proved to fit the Seattle traffic conditions reasonably well.)

(4) The WSDOT should investigate location specific thresholds to account for grade.

(5) Paired speed detectors should be installed throughout the system as the budget allows.

(6) WSDOT should investigate the use of additional occupancy ranges in the algorithm to improve the algorithm's performance.

(7) Further investigation is required to detect errors caused by detectors hanging on (long pulses).

(8) The error flagging techniques developed as part of this project should be implemented on the TSMC computer system. Data should be categorized as reliable or erroneous.

(9) The new computer system at the TSMC should contain a database system to facilitate data access by users without the intervention of TSMC personnel. This system should code data as reliable, suspect, or erroneous. The system should be accessible through dial-up modems. (If WSDOT decides to install speed detectors in the system, the database should be designed to handle speed and four bin vehicle classification data.)

CHAPTER 1

INTRODUCTION AND BACKGROUND

The Washington State Department of Transportation (WSDOT) has operated a computerized freeway traffic management system (FTMS) in the Seattle area since 1981. The FTMS incorporates ramp control, closed circuit television surveillance, electronic surveillance, variable message signs, highway advisory radio, graphic display of traffic conditions, a link to the computerized arterial control system, and incident management. The electronic surveillance system serves as the backbone of the FTMS, feeding traffic condition data either directly or indirectly to most of the other elements of the FTMS. The reliability of the data that the electronic surveillance system provides to the other elements of the FTMS, as well as to other systems, is critical to efficient and effective transportation management throughout the region. Although the current system includes some rudimentary data error checking, many detector failures and data errors remain undetected. To improve the reliability of the data from the electronic surveillance system, an improved error detection algorithm is needed.

Improvement is also needed in the way the system handles data that are flagged by the error detection algorithms. For control purposes, the current system ignores data that it flags as erroneous. However, the system places the erroneous data unchanged and unflagged in its database. When researchers, planners, and operators use the data from the database for analysis and evaluation, they must manually check the data for reasonableness. This process can be awkward and time-consuming. To better serve the needs of the users of the database, the system should include a method to flag suspect and erroneous data in its database.

The purpose of this report is to describe recent research undertaken by the University of Washington and WSDOT through the Washington State Transportation Center (TRAC) and the USDOT Regional Center, Transportation Northwest (TransNow), to develop improved data error detection algorithms for the WSDOT electronic surveillance system and to recommend methods to flag the erroneous data in the database once they have been detected. This chapter overviews the electronic surveillance system, the need for an improved error detection algorithm, and the need for flagging erroneous data in the system's database. Chapter 2 reviews previous and related work on this subject. Chapter 3 describes the procedures followed to develop the error detection algorithm. Chapter 4 discusses the results of the tests of the error detection algorithm. Chapter 5 describes the procedures followed to develop the erroneous data flagging techniques and database configuration recommendations. Chapter 6 discusses the erroneous data flagging techniques and the recommendations for a new database. Chapter 7 discusses implementation of the research results, and Chapter 8 details the study's conclusions and recommendations.

THE ELECTRONIC SURVEILLANCE SYSTEM

The WSDOT electronic surveillance system is made up of inductive loop detectors, detector amplifiers, microprocessor-based data accumulators (ramp controllers also perform data accumulation functions), the central FTMS computer at the Traffic Systems Management Center (TSMC), and the communication system that links the data accumulators or ramp controllers with the central computer (see Figure 1).

The system includes over 900 inductive loop detectors operating on the freeway mainline and on-ramps, HOV lanes, and collector-distributor roadways throughout the freeway system in the Seattle area. The system primarily uses three- turn, square, 6-foot by 6-foot loop detectors. One loop lies in each mainline lane at a given location. All the mainline loops in a given roadway direction at a location form a station. Stations are spaced at approximately one-half mile intervals throughout the metered sections of the freeway system. Outside of the metered sections, spacing varies; stations are placed at important locations to collect data and to provide driver information. The loops are

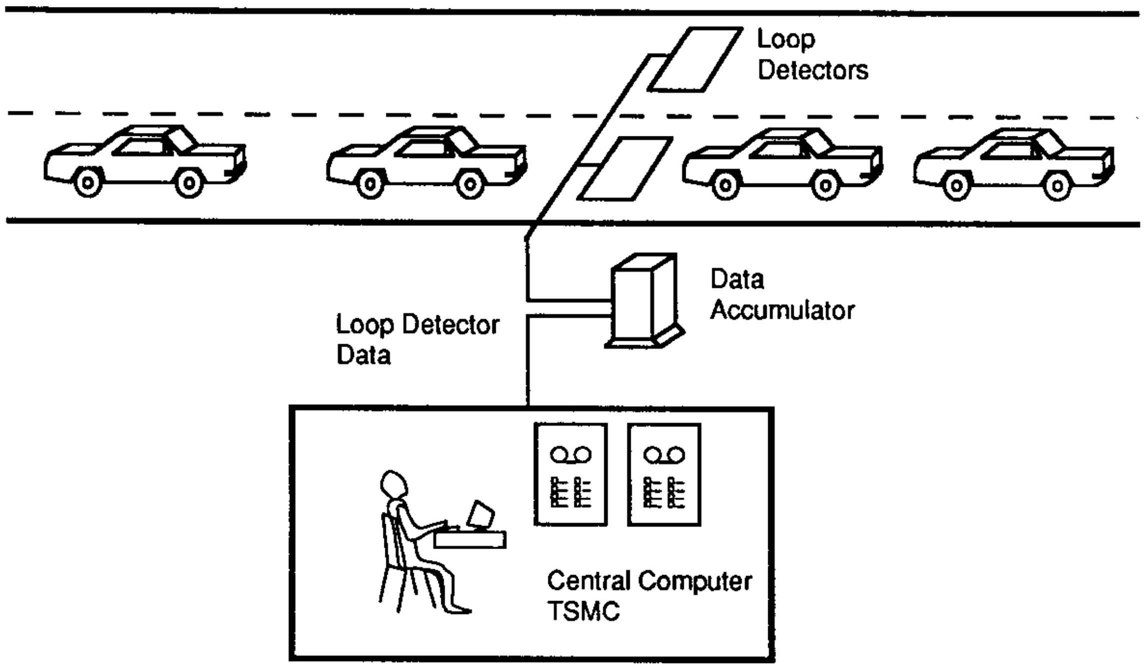


Figure 1. Electronic Surveillance System

connected to two- or four-channel self-tuning digital amplifiers in the field cabinets. The amplifiers scan the loops at 60 Hz.

The amplifiers' output feeds directly into the input channels of microprocessor-based data accumulators or ramp controllers. Seventy-one data accumulators and 24 ramp controllers operate in the system (Figure 2). (Several construction projects are under way to expand the number of loops, data accumulators, and ramp controllers in the system.)

The microprocessors scan the amplifiers' output 60 times per second. The microprocessors accumulate volume and lane occupancy data in 1-second buffers. (Lane occupancy is a measure of traffic density and represents the proportion of time that vehicles are present over, or "occupy," a traffic detector. Vehicle speed, traffic density or lane occupancy, and traffic flow or volume represent the three basic measures in traffic flow theory.) Lane occupancy is stored in the microprocessor as the number of 1/60-second scans of the amplifier output that show vehicle presence (high output) in a

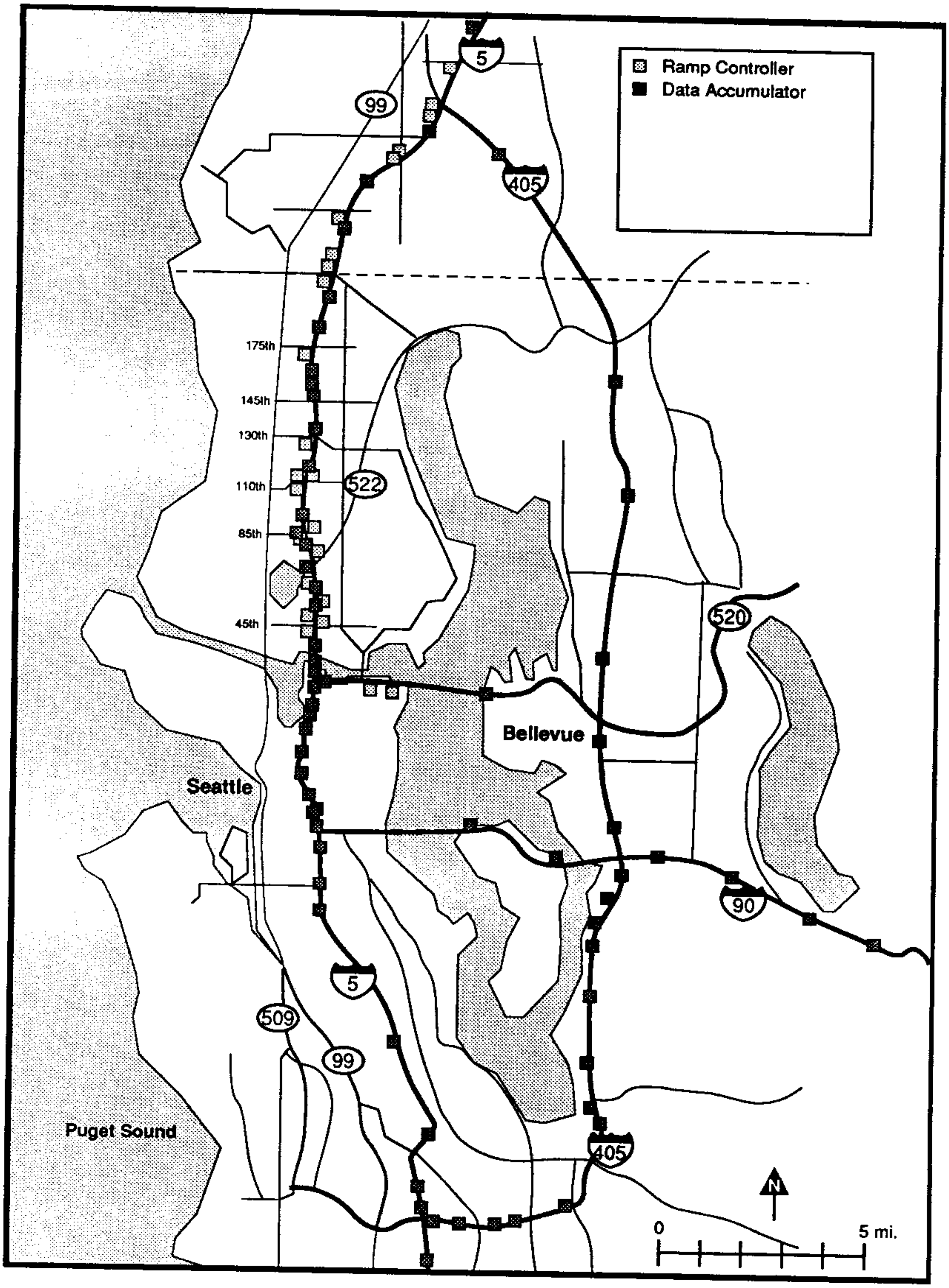


Figure 2. Electronic Surveillance System

1-second period. Vehicle volume is determined by the number of transitions from vehicle presence to vehicle absence (vehicle endings) in a second. Lane occupancy and vehicle volume are transmitted to the central FTMS computer once per second.

At the central computer, the 1-second data are accumulated into 20-second buffers. Lane occupancy is converted to a percentage in the 20-second buffers and stored in tenths of a percent. Four 20-second buffers are available; three contain data for the previous minute and one is being filled with the current 20-second data. The three full buffers form the 1-minute data that are the basis of all ramp control calculations.

The system accumulates data in 5-minute volume and lane occupancy tables. The 5-minute tables are double buffered so that all 5-minute data from the previous day are maintained in the system while the current day's 5-minute data tables are being filled. The 5-minute data form the basis of routine data reports and archived data. Once per day, the previous day's 5-minute volume data are written to magnetic tape for historical archiving. Data on magnetic tape are available for all 5-minute intervals collected over 24 hours a day since July 1981, although some days are unavailable because of system failures. The data are stored in a standard tape format readable by most computer systems that have an appropriate tape drive.

Other data sources are available. Five-minute volume and lane occupancy reports for all freeway stations are stored in text form on microfiche. These reports cover morning and afternoon peak periods (6-10 a.m., 3-7 p.m.). Additional microfiche data provide hourly volume 24 hours/day in controller reports. Special 20-second, 1-minute, or 5-minute data reports can be scheduled for on-line collection for limited numbers of loop and/or station combinations, along with daily summaries for specified loops or stations. These special reports can be either printed or written to magnetic tape for transfer to another computer.

The existing system was designed solely for the use of the system operators. The data reports mentioned above were supplied to meet the needs of the operators. However, because of the amount of data available from the system and the lack of detailed freeway traffic data from other sources in the Seattle area, transportation professionals from outside the TSMC have placed a substantial demand for data on the operators of the system. The system was not designed to provide the type of data requested, but the data can be produced in a rather awkward manner. All access to data must be arranged through contact with TSMC personnel. TSMC must schedule the reports and oversee report production. Summary information is usually unreliable because data errors are not detected and erroneous data often are printed in the reports. TSMC personnel often must check each piece of data to assure its reasonableness. This process places an unreasonable burden on the personnel at TSMC.

The system is also awkward from the potential outside user's perspective. There is no provision for outside users to access data on the tape archive except by borrowing and copying the tapes onto their own systems. The microfiche reports are the only historical record of lane occupancy. Users must first photocopy the reports and then enter the data by hand if they wish to use them. The special reports must be scheduled in advance at the TSMC, subject to personnel availability at the TSMC. The reports often must be scheduled several times because of system errors or other priorities overriding the scheduled reports.

In short, the data collection and dissemination methods at the TSMC were initially designed to serve in-house needs. There is almost no provision to serve non-WSDOT users. Because many of these data can only be extracted from the TSMC system, there is a substantial demand for these data on TSMC personnel. However, the limitations of the TSMC's computer resources and the substantial requirements data requests place on staff time mean that at best only very restricted use of data can be granted to outside users. Clearly, given the value and unique nature of the system's data, improvements in the existing database and reporting functions are necessary to make the data more accessible and to reduce the impact on TSMC staff time.

DATA ACCESS AND STORAGE AT UW

The Department of Civil Engineering at the UW maintains a tape library of 5-minute volume data similar to that maintained at the TSMC, and in fact the UW's tapes have been copied from borrowed TSMC tapes. In addition, a FORTRAN program written by a former UW graduate student allows a user to select freeway locations, dates, and times of day and then transfers the selected data items to disk files interpretable by the relational database manager UWRIM. Some limited processing can then be done with UWRIM, or the data can be edited, formatted, and written to files for input into other application programs. The UWRIM database is also configured to handle lane occupancy data, even though they are not currently available on tape.

From December 1985 to June 1986 a WSDOT research demonstration project maintained a telecommunications link between the TSMC's computer and the UW's CYBER. (1) The system transferred data files containing 5-minute volume and 5-minute lane occupancy measurements to the CYBER across a dedicated data line. These files were then stored on computer tape. In addition, a special summary program computed daily summary statistics (morning and afternoon peak hour volumes, total volume, maximum and minimum flows) for selected locations and stored these in disk files for later computation of weekly and monthly ADT and AWDT. However, the high cost of renting the equipment necessary for the Telecom link led to its discontinuance in the summer of 1986.

The University's database is available to any user willing to obtain an account on the University's CYBER computer. However, the costs to outside users are substantial (the University bills outside users, including the WSDOT, at higher rates than it does academic users). When compared to the apparently free data available at the TSMC, it is not surprising that to date only researchers at the University have used the database, even though outside users have been aware of its existence and have expressed interest in its use. Although this lack of use seems to be due primarily to the cost of using the database, the unfriendly nature of the Cyber computer in general and the tape reading software in particular are certainly contributing factors. For instance, a user wishing to obtain the ADT for a particular freeway location first has to read the appropriate raw data from tape to UWRIM, format these data for input into a spreadsheet program, and then program the spreadsheet to calculate ADT. Alternatively, the user may write a FORTRAN program that can use data in UWRIM files to calculate ADTs directly. Either way, the task involves more interaction with the CYBER system than outside users find comfortable. In addition, like the data located at the TSMC, erroneous data are not screened from the database. Data going into the summary or statistical analysis must be screened manually in order to be reliable.

To summarize, although the UW has the potential to provide a useful service to outside data users, this potential has not been realized, primarily because access is neither free nor friendly. WSDOT personnel are understandably reluctant to rely on the UW for data when similar information can be obtained directly from the TSMC.

EXISTING DATA RELIABILITY TESTS

The current detector data reliability algorithm at the TSMC diagnoses and, in some instances, corrects errors at two levels: microscopic and macroscopic. The microscopic level refers to detector error identification that occurs as the microprocessor scans and processes detector pulses. The term macroscopic refers to the diagnosis of detector errors at the central computer site after the data have been aggregated over time.

As implied above, the microscopic error detection routines for the WSDOT system reside in the field microprocessors. There are three basic microscopic tests in the field. First, if the amplifier registers a vehicle presence for less than 1/15 of a second (four scans, each 1/60 of a second), the microprocessor considers the pulse(s) to be indicative of a spurious detection and ignores the pulse(s). On the other hand, if the microprocessor's scan of the amplifier shows a vehicle presence followed by an absence (called a "gap") lasting less than 1/15 of a second, the microprocessor disregards the gap and treats the pulses as continuous throughout the particular time period. This procedure, in effect, adjusts the volume and occupancy to account for, or ignore, short "drop outs" in presence and short, spurious detector actuations.

A second microscopic procedure programmed into the microprocessor flags pulses as unreliable if the microprocessor senses more than two valid pulses (vehicle endings) in a second. In this case, the microprocessor sets all bits in the 8-bit, 1-second data byte for the detector in question to "1", which represents 105 percent occupancy and a volume of three vehicles in a second. The central computer ignores the data for that 1-second period for the malfunctioning detector, flags the detector as providing suspect data, and provides a message to the operator that the detector has provided unreliable data.

A third microscopic detector data reliability check the microprocessor performs compares detector on-times and off-times against programmable variables. The microprocessor monitors detector on-times (representing vehicle presence) to see whether they remain on for longer than a program variable, usually set to 3 minutes. It also monitors detector off-times to see whether they exceed a second programmable variable, usually set to 255 minutes (the off-time threshold is high to avoid false alarms from express lanes that are sometimes closed and HOV lanes). Each microprocessor has a unique on-time parameter and a unique off-time parameter. However, one on-time and one off-time parameter are used for all detectors the microprocessor scans. If any detector is on too long or off too long, the microprocessor sends back an alarm to the central computer indicating that the detector has failed. The central computer then ignores the data coming from the detector for control purposes and sends a message to the operator that the detector has failed. The detector continues to be flagged as failed until the failed condition has cleared, as determined by the same monitoring routine in the microprocessor. Since the FTMS utilizes amplifiers that tune themselves through feedback circuitry, unusual on-times and off-times must be caused by loop detector malfunction rather than simple maladjustment.

The FTMS uses two macroscopic detector data reliability tests, represented in Figure 3. The central computer, receiving its data from the various microprocessors, checks to see whether freeway traffic volumes are too high or too low. The algorithm looks for volumes that are less than a system threshold parameter, usually set to two vehicles, during a 5-minute period (or less than 24 vehicles per hour). It also looks for volumes that are greater than a second system threshold parameter, usually set to 250 vehicles per 5-minutes (or 3,000 vehicles per hour).

The second macroscopic reliability check is based on occupancy. If the occupancy from a detector exceeds a program variable (usually set to 90 percent) for a 5-minute period, the algorithm flags it as failed. The data from the detector are ignored for control purposes until the occupancy level falls below the threshold. The system alerts the operator to the failure through an alarm message.

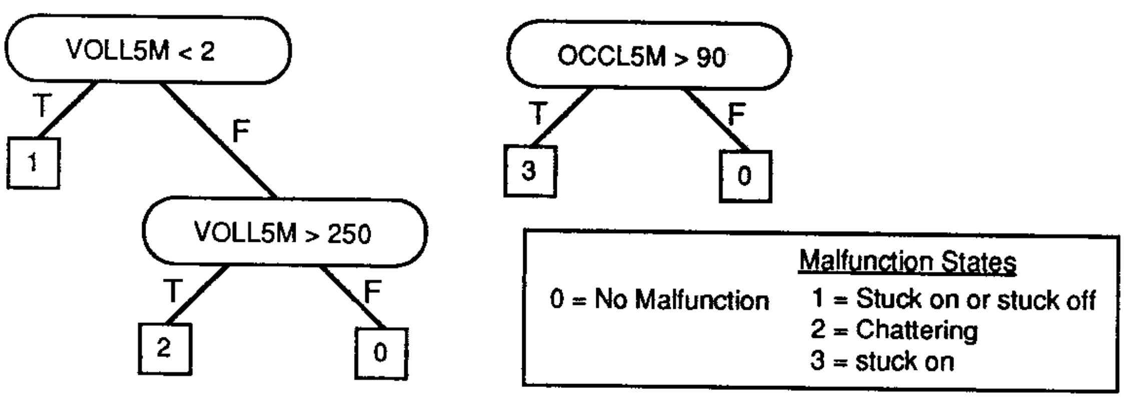


Figure 3. Existing Macroscopic Detector Data Reliability Algorithm

THE NEED FOR IMPROVED ERROR DETECTION

A major consideration in any automatic data collection and storage method is the detection and identification of data errors. Without such identification, the quality of the database is compromised, and data users must employ time consuming visual inspection of all data before they can be used. The data reliability tests programmed into the current system detect some of the gross errors that can be encountered in a loop detector-based electronic surveillance system. However, other malfunctions remain undetected. Inaccurate data get into the system without a way of being detected.

In a 1976 FHWA report, Development and Testing of Incident Detection Algorithms, Volume 2: Research Methodology and Detailed Results, the authors listed five ways in which detectors can malfunction: (1) stuck sensors (on or off position), (2) chattering, (3) pulse break up (pulsing), (4) hanging (on or off), and (5) intermittent malfunctioning. (2) WSDOT's existing detector data error identification algorithm already automatically identifies many of the malfunctioning detector states.

First, when detectors are on too long (longer than about 3 minutes) or off too long (longer than about 255 minutes), the algorithm considers the detectors to be malfunctioning (stuck sensors). Second, the system can identify and flag detectors that produce very rapid, short pulses (chattering). By setting occupancy to 105 percent and volume to three vehicles, the system flags unreliable 1-second data when more than two valid pulses occur in that second. The macroscopic data check that identifies 5-minute volumes that are less than two or greater than 250 also responds to chattering, as well as the stuck sensor malfunction state. Third, by screening and correcting for spurious pulses and pulse gaps, the system eliminates the pulse break up (pulsing) state of malfunction. However, the fourth and fifth malfunction states, hanging and intermittent operation, are not reliably detected in the current FTMS system. The hanging detector yields accurate volume but inaccurate occupancy data. Detectors that hang on result in high occupancy. This malfunction occurs when the detector pulses are too long. Detectors that hang off result in low occupancy. This malfunction occurs when the detector pulses are too short. Many of the control algorithms in the system are based on occupancy or use occupancy as threshold values for decision-making or for graphic display of conditions to the operator. Therefore, detection of this source of error is critical. Only when detectors hang on for long periods of time (usually 3 minutes) does the system identify the failure through the detector on-time check. (This situation really falls into the stuck failure category.) Detectors hanging on for a period of time shorter than 3 minutes and detectors hanging off (short pulses) are not detected.

In summary, the existing error detection schemes are useful in detecting stuck sensors, chattering, and pulse break up. However, improvements are required to detect hanging detectors and intermittent malfunctions. These are the most difficult failures to detect, either electronically or manually.

THE NEED FOR FLAGGED ERRONEOUS DATA

As mentioned previously, the TSMC employs some simple error checks of detector data. However, the system uses the error detection only for its primary function in the ramp metering routines. No checking and screening of data were designed into the system for data entering the database because these needs were unforeseen when the system was designed. Therefore, data users have found that the data must be studied in raw form before being processed, and laborious editing has been needed to prepare the data for analysis. (The inability to discriminate between valid and erroneous data was identified as a major obstacle to developing an automatic summary statistic generating procedure in the second phase of the TELECOM project.) Thus, because of the need to supply these important and unique data to the transportation community, it is critical to identify erroneous data in the database to ensure the accuracy of the data and to minimize personnel requirements to analyze the data. The research described here involved two major elements:

(1) detecting intermittent and hanging detector failures, and

(2) recommending methods to flag erroneous data in the FTMS's database.

The research focused on detecting intermittent failures and hanging errors because they are not detected in the current system; they are difficult to detect manually; and WSDOT personnel believed they were the most prevalent errors in their system. WSDOT personnel also felt that, in order to be effective, the algorithm had to provide very few, if any, false alarms. If the algorithm identified failures that did not exist, operators would soon ignore the results. They preferred to see some errors remain undetected rather than have a high false alarm rate.

For flagging errors in the database, the researchers were primarily concerned with making the database useful and accessible to potential users of the data while minimizing the personnel requirements at the TSMC to provide accessibility.

CHAPTER 2

REVIEW OF RELATED WORK

Researchers conducted a literature review to investigate how other freeway management systems have coped with detector malfunction and data reliability problems. (3) Of the various automatic detector failure identification methods reviewed, two seemed worthy of further scrutiny.

First, researchers at the University of California's Institute of Transportation Studies (ITS) developed an algorithm that compares a detector's average on-time in a mainline lane to the average on-time of all the detectors at the detector's station. (4) The algorithm is similar to the CALTRANS occupancy test but is more robust and causes fewer false alarms. However, a disadvantage of the ITS algorithm is the expensive and time consuming calibration (the historical speed distribution factor) of detectors that is necessary. The calibration is necessary so that the on-time comparisons can account for intra-stational and inter-stational differences in freeway traffic flow behavior -- factors that may reduce a detector comparison algorithm's reliability. The effect of lane detector location on the interaction among volume, occupancy, and speed has not only been discussed in the literature, it was also apparent during a preliminary data analysis that used the comparison method. However, the ITS algorithm has demonstrated the advantage of using the volume and occupancy relationship to identify the hanging on and hanging off malfunction states.

A second disadvantage of the ITS algorithm is that the software in each field microprocessor would have to be modified to be useful in Washington. The research team chose to direct its efforts toward algorithms that could be installed at the central computer to ease programming and speed implementation.

The second approach of interest found in the literature was the single detector (sensor) algorithm, which tests typical detector data (volume, occupancy, and speed) against certain realistic threshold values at various time intervals. (2, 5) The single detector approach can identify many malfunctioning detector states, and when tests are performed at short time intervals, it can identify intermittent erroneous data. The WSDOT's microscopic algorithm can be labeled a single detector algorithm operating at the microscopic level. Of the different tests the single detector algorithms can perform, the speed threshold test had the greatest potential for improving the existing algorithm. However, in the WSDOT's FTMS, speeds cannot be measured, they must be estimated.

The method commonly used to estimate speeds when direct measurements are impossible is to multiply a constant by volume and divide by occupancy. The problem with the speed threshold test, which uses volume and occupancy data, is in identifying the value that the constant should be. If the relationship among speed, volume, and occupancy is accurately defined, a test can be devised to screen volume/occupancy ratios, identifying those that imply implausible speeds as unacceptable. Each of the malfunction states that the current system does not detect (hanging detectors and intermittent malfunctions) should produce volume/occupancy ratios that are out of balance. Therefore, the speed threshold algorithm was selected as the most appropriate for further investigation and development.

The literature has typically represented the relationship between volume, occupancy, and speed with the fundamental equation of traffic flow (Equation 1)

$$q = u * k \qquad \text{(Equation 1)}$$

where, q = flow (vehicles/hour),

u = speed (miles/hour), and

k = density (vehicles/mile).

This equation assumes uniform traffic flow. Equation 2,

$$k = g * o \qquad \text{(Equation 2)}$$

where, k = density (as above),

o = occupancy (in percent), and

g = constant,

assumes that occupancy and density are linearly related. (6) Typically, plots of volume and occupancy have been explained by a discontinuous, two-regime model characterized by a gap between uncongested and congested regimes. (7, 8) Recent investigations by Hall et al. (6, 9, 10, 11, 12, 13) and others have indicated that g is not a constant. The primary focus of Hall's investigation was Equation 3 (as derived from Equation 2 above),

$$u = q / (o * g) \qquad \text{(Equation 3)}$$

where, $g = K / (\text{vehicle length} + \text{detector length})$,

K is a conversion factor, and

q, o, and u are as defined above.

By this method, the g-factor can be used with volume and occupancy to estimate speed without assuming that g is constant.

Hall and Persaud collected 30-second volume, occupancy, and speed data from median lane paired inductive loop detectors at four different stations from the Burlington Skyway and Mississauga FTMSs on Queen Elizabeth Way in Ontario, Canada. They calculated the g-factor for each 30-second period from each detector's volume, occupancy, and speed and checked for measurement error by confirming speeds with videotape. Hall and Persaud reached two important conclusions relevant to the calculation of speed from volume and occupancy. They stated,

> First, the use of a constant value of g for all traffic conditions at a single station appears to give biased estimates of speeds. If g is estimated for free-flow conditions, the estimates of speeds under any conditions will be consistently lower than actual. If g is estimated for higher flow uncongested conditions, then estimates of free-flow speeds within congested conditions will be lower than actual. The best procedure at present would be to use a sliding value of g, which changes with occupancy.
>
> Second, even under equivalent traffic conditions, the value g does not appear to remain constant across a number of stations, at least when major changes in grade are present. Hence it would appear to be necessary to calibrate g separately for each set of geometric conditions. (14)

Hall and Persaud's findings showed that it is possible to calculate speeds from volume and occupancy, but that the use of one constant with all occupancies and their associated volumes is not advisable. This conclusion led the Seattle research team to move forward with the speed threshold method of detector error testing. They used Hall's findings on g-factors to develop a multi-threshold routine that uses occupancy values to determine the appropriate threshold conditions.

CHAPTER 3

ERROR DETECTION ALGORITHM DEVELOPMENT

The research team used Hall's findings as a basis to improve the WSDOT error detection algorithm. The new, improved algorithm uses 20-second volumes, 20-second occupancies, and 5-minute occupancies to identify erroneous data. As stated above, the existing algorithm identified chattering and stuck sensors and adjusted for pulse break-up, but it did not identify hanging or intermittent malfunctions. The improvements were primarily aimed at intermittent and hanging malfunctions. The new algorithm works at the macroscopic level.

The new algorithm can be broken into two parts, the part that involves 20-second data and the part that involves 5-minute data. The part of the new macroscopic algorithm that uses 20-second data identifies invalid detector data if one of the following conditions occurs (see Figure 4):

(1) 20-second lane volumes (VOLL20S) are greater than 17 (3060 vehicles per hour equivalent),

(2) 20-second volume/occupancy (V/O) ratios are outside the threshold ranges for four occupancy ranges (0.1-7.9 percent, 8.0-25.9 percent, 26.0-35.9 percent, and greater than 36.0 percent), or

(3) 20-second volumes are greater than 1 when occupancies are between 0 and 0.1 percent.

The second part of the algorithm screens 5-minute occupancies. Occupancies greater than 90 percent are considered indications of unreliable data (see Figure 5). This screen is essentially the existing 5-minute high occupancy check. This test identifies severe hanging on malfunctions that may not fail the detector on-time test in the field.

The high 5-minute volume check in the existing algorithm will be unnecessary with the new 20-second volume test (see item 1 above). Hall and Persaud state that

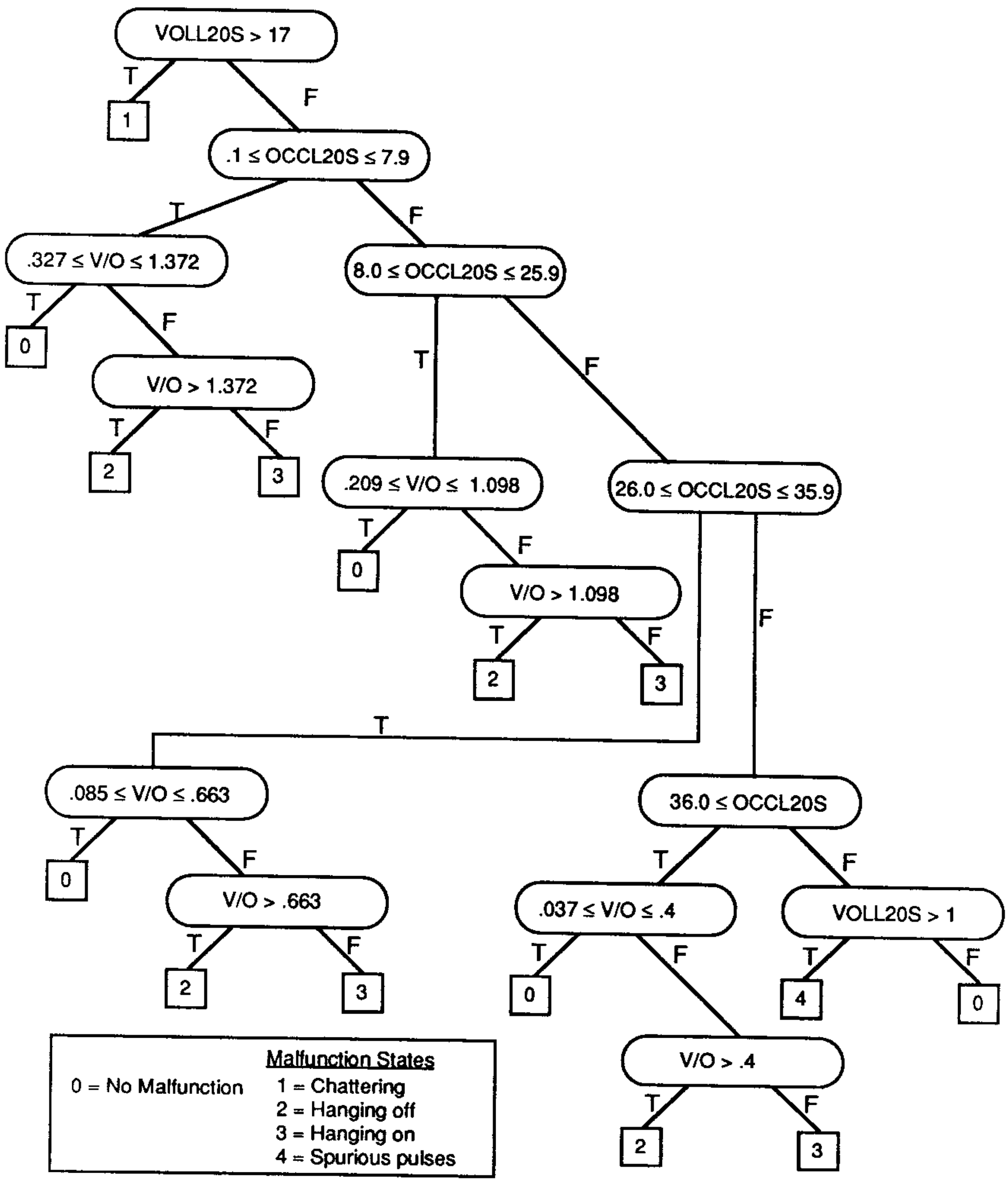
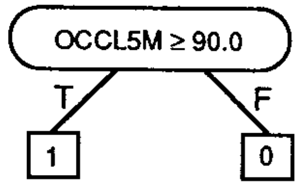


Figure 4. Proposed Macroscopic Detector Data Reliability Algorithm Part I



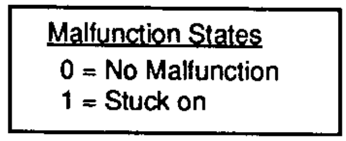


Figure 5. Proposed Macroscopic Detector Data Reliability Algorithm Part II

30-second volumes greater than 25 (3,000 vehicles per hour) are not likely. This rate converts to about 17 vehicles in a 20-second period.

The lower 5-minute volume check (less than two vehicles in 5 minutes) was eliminated because the algorithm might have identified data that were the result of late night or early morning traffic conditions as erroneous. The same problem would occur for a lower 5-minute occupancy threshold.

The remainder of this chapter focuses on describing the part of the algorithm that deals with 20-second data, particularly the volume/occupancy ratio test. The volume/occupancy ratio threshold values and the occupancy ranges used in this algorithm were derived entirely from three of Hall's data sets. They contained 30-second volume, occupancy, and speed data collected by Hall and Persaud on the Burlington Skyway and Mississauga FTMSs. These data were used because the WSDOT's single inductive loop detector system is unable to collect speed data directly. (The volume/occupancy ratio thresholds were tested on volume and occupancy data collected from the WSDOT FTMS to verify the validity of using the Canadian data.)

The occupancy ranges were introduced in recognition of relationships Hall and Persaud noticed between g-factors and ranges of occupancy. The ranges Hall and Persaud presented were low (1-7 percent), medium (8-25 percent), and high (25 percent or higher). The research team divided the high occupancy regime into two categories to reflect the increased g-factor scatter Hall found in the high range.

The researchers calculated the maximum and minimum volume/occupancy ratios for each occupancy range by applying Equation 3 to the appropriate maximum speed, minimum speed, and g-factor value. For each of his data sets, Hall calculated the average g-factor and the 95 percent confidence interval for each occupancy value observed (in whole percentages). (Larger single value occupancies were grouped together because of the limited number of observations.) The research team obtained Hall's raw data sets. In investigating these data, the researchers discovered several unlikely speed observations in two of the data sets. Table 1 describes the questionable data. The research team

Table 1. Data Eliminated from Hall and Persaud's Data Sets Due to Unreasonable Speed Based on Occupancy

	Description of Unreasonable Observations		
Station	Occupancy (%)	Volume (vph)	Speed (mph)
SB5	50	1680	45.95
	58	1020	47.82
	61	960	51.54
NB7	7	240	14.28
	8	118	73.28
	9	120	9.32
	15	360	13.66
	56	960	75.14
	59	1440	59.62

eliminated the suspect data and recalculated the average g-factors and the corresponding 95 percent confidence intervals. The researchers averaged the upper limit and lower limit of the 95 percent confidence bands for the recalculated g-factors for all occupancy values in each of the occupancy ranges for each data set. Then, they determined the maximum and minimum speeds for each occupancy range within each data set. Finally, the researchers selected the minimum and maximum g-factors and speed from all the data sets for each occupancy range and used these values to calculate the maximum and minimum volume/occupancy ratios for each occupancy range, as shown below. From Equation 3,

$$v / o = (u * g) / 180 \qquad \text{(Equation 4)}$$

where, v = 20-second volume,

the 180 factor converts hours to 20-second periods, and

o, u, and g are as defined in Equation 3.

For each occupancy range, then, the volume/occupancy ratios were restricted to upper and lower thresholds on the basis of Hall's data. In other words, for a particular occupancy range, r,

$$(u_{minr} * g_{mllr}) / 180 \leq v / o \leq (u_{maxr} * g_{mlur}) / 180 \qquad \text{(Equation 5)}$$

where, u_{minr} = minimum speed for occupancy range r,

g_{mllr} = mean lower limit of the g-factor for occupancy range r,

u_{maxr} = maximum speed for occupancy range r,

g_{mlur} = mean upper limit of the g-factor for occupancy range r, and

r = 1, 2, 3, 4, representing occupancy ranges of 0.1 - 7.9, 8.0 - 25.9, 26.0 - 35.9, and $\geq$ 36.0 percent, respectively.

The volume/occupancy ratio thresholds were considered to be conservative estimates of the g-factor and occupancy patterns. The g-factor thresholds were not derived from standard statistical pattern recognition parameters for normal distributions because the data were not collected from a random sample; some stations had more observations than did others. Of course, where needed, calculations received the appropriate metric and 30- to 20-second conversions. Table 2 summarizes the volume/occupancy (v/o) ratio calculations. Figure 6 represents the v/o thresholds graphically. In addition, Figure 6 shows the 20-second volume threshold. The area between the shaded area represents 20-second data that the algorithm considered reliable. The algorithm determined data to be erroneous if they fell outside the heavy solid lines.

Table 2. Summary of Threshold Calculations

	Occupancy Ranges			
	.1 - 7.9	8.0 - 25.9	26.0 - 35.9	36.0 +
Minimum g factor	2.433	2.024	1.754	.980
Maximum g factor	3.132	2.526	2.462	1.868
Minimum speed (mph)	24.22	18.63	8.69	6.83
Maximum speed (mph)	78.87	78.25	48.44	38.5
Minimum 20 second volume/occupancy ratio	.327	.209	.085	.037
Maximum 20 second volume/occupancy ratio	1.372	1.098	.663	.400

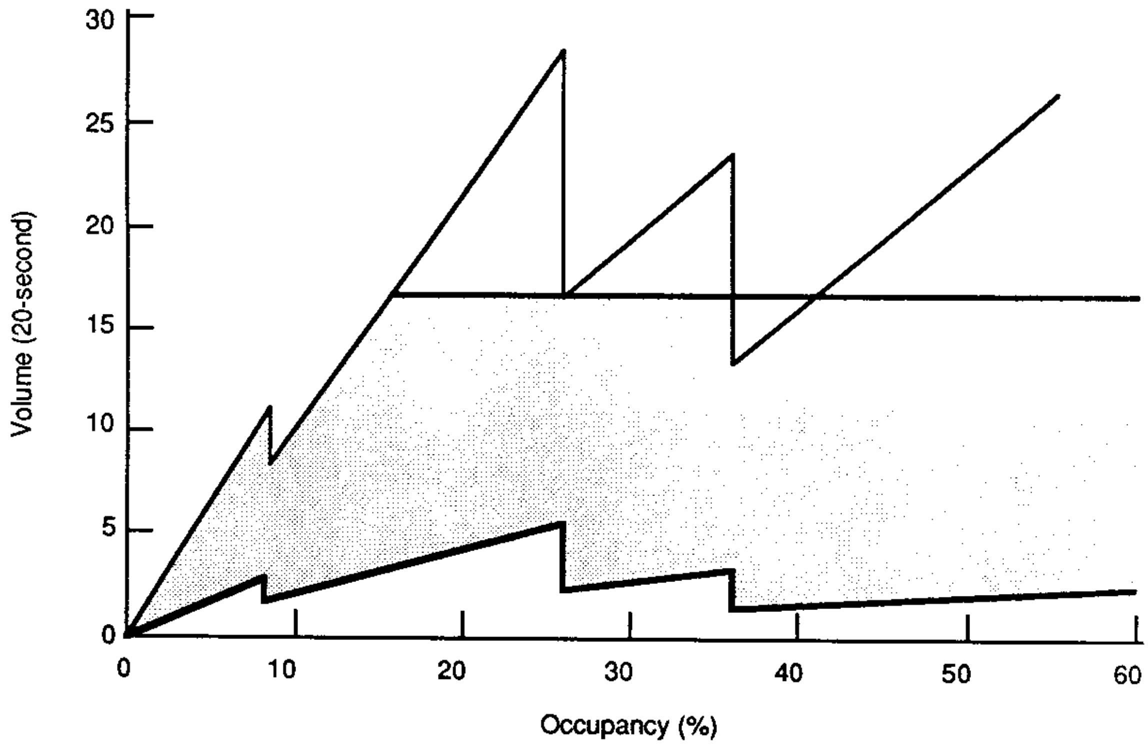


Figure 6. 20-second Threshold Test Improvements for WSDOT Macroscopic Detector Data Reliability Algorithm

CHAPTER 4

THE ERROR DETECTION ALGORITHM TESTS

The proposed detector data reliability algorithm was tested on 20-second volume and occupancy data collected at three different mainline stations on I-5 north of downtown Seattle (see Figure 7 and Table 3). There were some time gaps between observations because of limitations in the report scheduling software that required interim data to be printed before additional data are stored. Weather conditions were good (dry), and no incidents were reported during the entire collection period.

For the detector stations to be selected as data collection sites, they had to meet two important requirements. First, the detectors at the particular station had to be generating reliable data. Two steps were taken to ensure this. First, WSDOT personnel selected stations in which they had confidence based on the detectors' past performance. Second, during the data collection periods traffic flow was videotaped at the collection site to confirm the accuracy of the volume data. Occupancy data accuracy are difficult to confirm precisely without a relatively sophisticated videotaping experiment or direct speed data, but an observer can determine whether the occupancy values are feasible for the corresponding traffic conditions.

The second requirement for the data collection sites was that they be on freeway segments with different grades. (15) Station 283 was located on -.755 percent grade; Station 228 was located on a +2.040 percent grade; and Station 229 was located on a -1.8169 percent grade (see Figures 8 and 9).

The researchers developed a test of the algorithm to see how many false positives (false alarms), false negatives, and successful unreliable data identifications were found when the proposed macroscopic algorithm was applied to both data generated by simulated detector malfunction and apparently reliable data. WSDOT personnel simulated the detector malfunctions by taking the following actions:

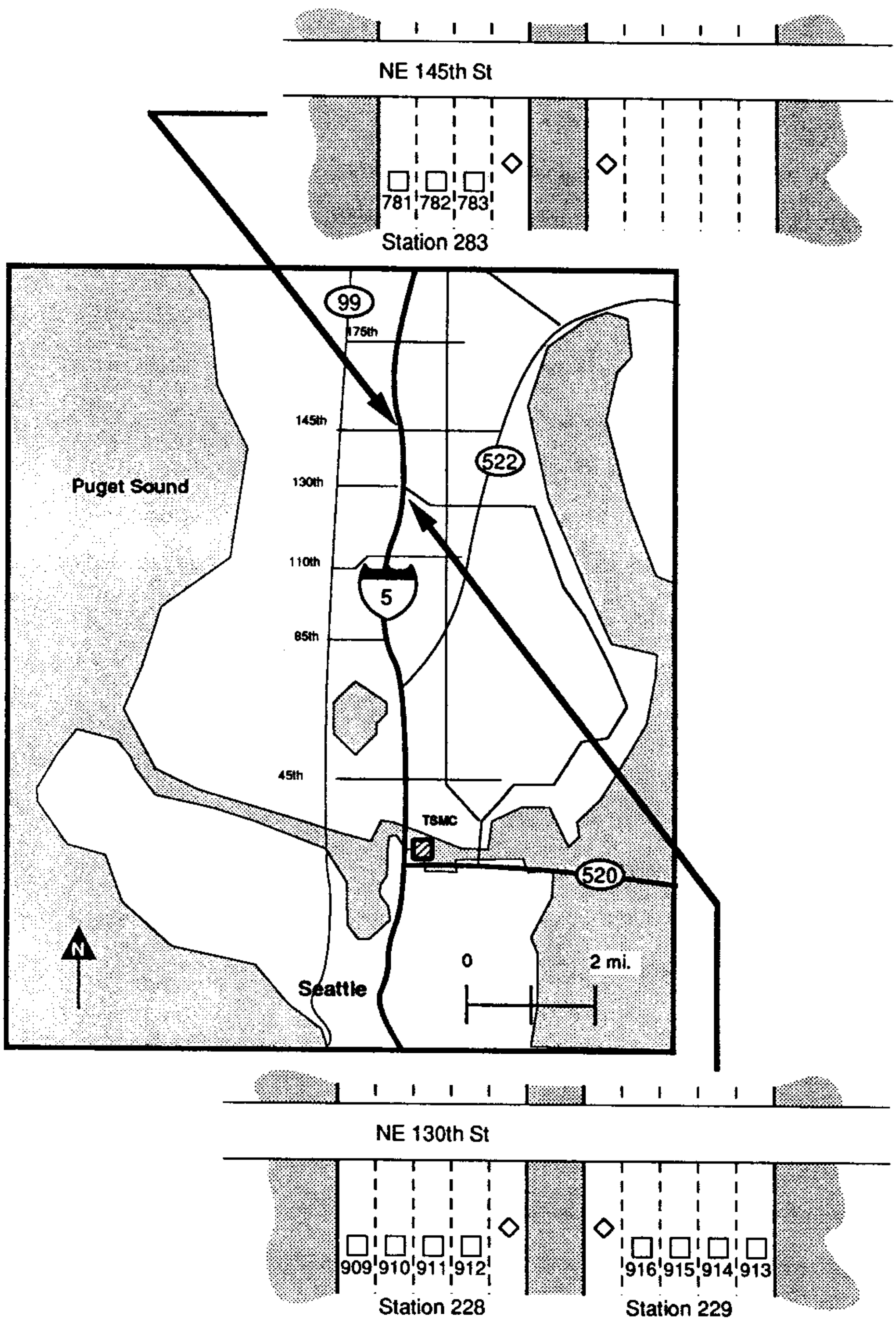


Figure 7. Detection Test Site Locations

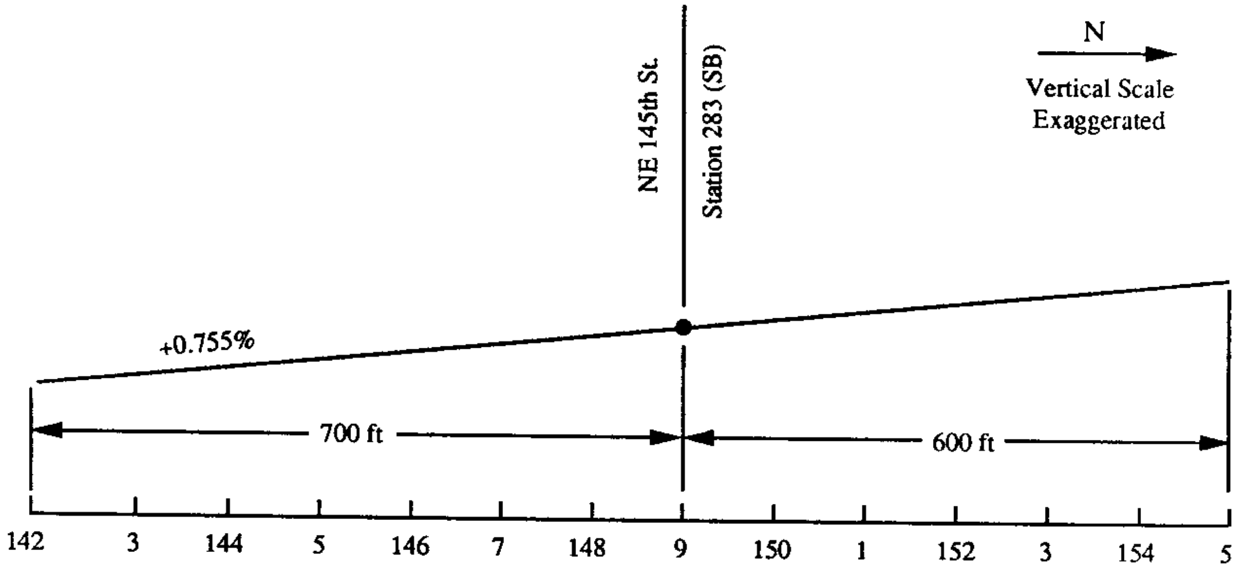


Figure 8. Vertical Profile of Interstate 5 at 145th Avenue, Seattle Washington

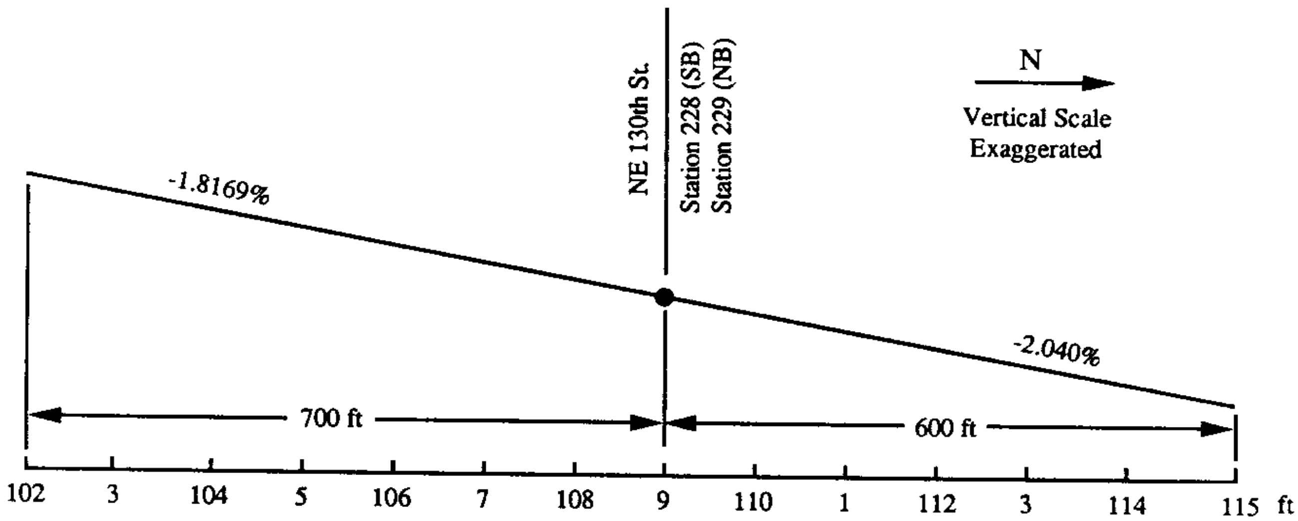


Figure 9. Vertical Profile of Interstate 5 at NE 130th Avenue, Seattle Washington

Table 3. I-5 Data Collection

Station	Location	Detectors	Data Collected	Time Period	Number of Observations
228	NE 130th Southbound	909, 910, 911, 912	6/15/89	8:20 - 9:15	135
229	NE 130th Northbound	913, 914, 915, 916	5/16/89 6/20/89	15:35 - 17:30 15:40 - 16:55	270 135
283	NE 145th Southbound	781, 782, 783	5/18/89 6/15/89	7:25 - 9:20 8:00 - 9:15	270 180

(1) changing the amplifier from presence to pulse mode,

(2) changing sensitivity levels (high or low), and

(3) manually placing actuations through the cabinet's detector display panel.

Before WSDOT personnel began simulating detector errors, they allowed the detector to generate data unhampered. That way the researchers could confirm that the detectors were operating properly. A closed circuit television system provided a visual record of the traffic conditions during the initial portion of the test when no malfunctions were being simulated. The tape, as mentioned previously, provided a means to confirm the accuracy of the data before the simulation of detector malfunctions began.

The tests were conducted in no specific order. WSDOT personnel noted the time, action taken, and detector number each time they simulated a detector malfunction. The researchers obtained data reports from the FTMS on magnetic tape. The reports contained 20-second volume and occupancy data. Researchers were not aware of specific times that the tests would be performed nor of the order in which they were performed until after they had analyzed the data. The researchers applied the algorithm presented in Figure 4 to each 20-second period. They included a persistence check. Data from any given detector that the algorithm flagged in two out of three 20-second observations within a moving 1-minute period were considered to be erroneous. The researchers compared the results of the algorithm with the field notes taken by WSDOT personnel to determine the algorithm's ability to detect simulated malfunctions. The researchers also hand checked the data for reasonableness. This procedure was necessary to determine the validity of data that the algorithm flagged when WSDOT personnel were not intervening with the detector pulses.

During the early development work on the algorithm, one data station (Station 33) that was being considered as a possible test location produced data that fell outside the thresholds when no errors were being simulated. Figure 10 shows the volume/occupancy ratios from this station superimposed on the data reliability envelope presented in

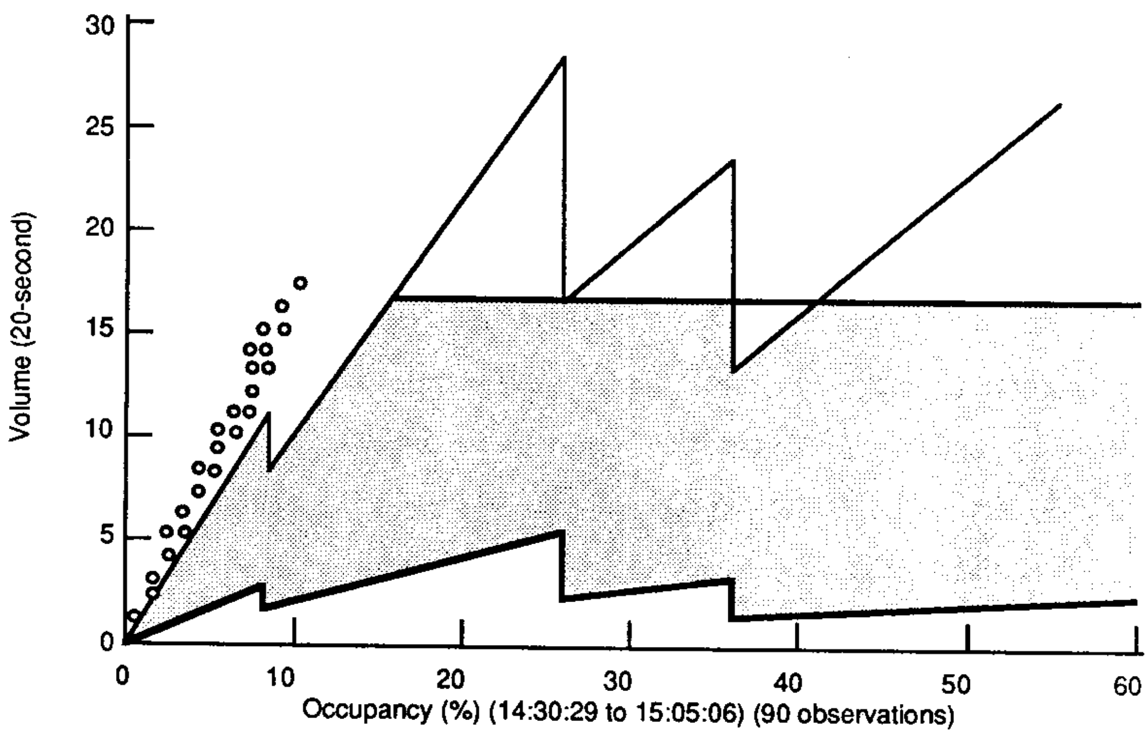


Figure 10. Station 33 Volume and Occupancy Observations with Thresholds (data collected on April 18, 1989)

Figure 6. WSDOT personnel field checked the station and confirmed that the detectors were malfunctioning (short pulses). The algorithm was able to identify the detectors as malfunctioning even though the WSDOT personnel had been confident in the reliability of the station. (The erroneous data from Station 33 closely resembled data WSDOT personnel generated later by placing the amplifier in pulse mode.)

During the testing phase of the project, the algorithm again detected actual detector malfunctions, this time at Station 283. As was the case mentioned above for Station 33, WSDOT personnel had had confidence in the reliability of Station 283. In fact, unlike Station 33, Station 283 was in the ramp control section on I-5. The central computer had been making control decisions using data from this station. The algorithm detected almost continuous errors at Station 283 before intervention and throughout the test period (Figure 11). WSDOT went back to the site to troubleshoot the problem. After making the required adjustments and repairs, personnel collected data from the site on June 15th without the intervention of the test procedures. The algorithm indicated that the data from these detectors were valid during this non-intervention period (Figure 12). This situation again indicated that the algorithm detects errors that are not detected in the current system. Figure 12 also gives a good indication that the thresholds selected using the Canadian data fit the conditions on the Seattle freeway system.

Figures 13 through 15 show representative results of the algorithm and the corresponding actions taken in the field to simulate malfunctions. The algorithm was particularly effective at identifying the hanging off (short pulse) malfunction, which WSDOT personnel simulated by changing a detector's amplifier mode from presence to pulse. (See Figure 13 and Table 4 for an example from Detector 914.)

The algorithm was not successful in detecting long pulse (hanging on) malfunctions. By increasing the amplifier's sensitivity, researchers simulated a detector hanging on. This situation produced unrealistically high occupancy (Table 5). The algorithm did not detect this malfunction any time it was simulated (Figure 14). An

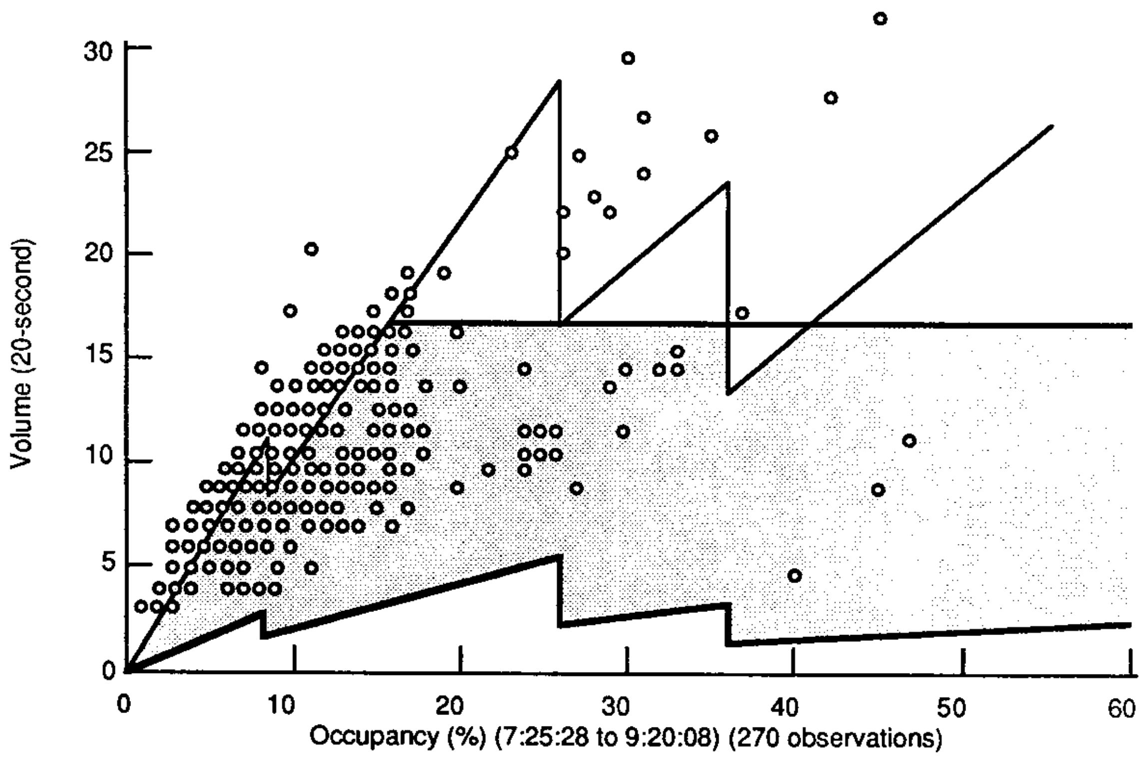


Figure 11. Station 283 Volume and Occupancy Observations with Thresholds (data collected on May 18, 1989)

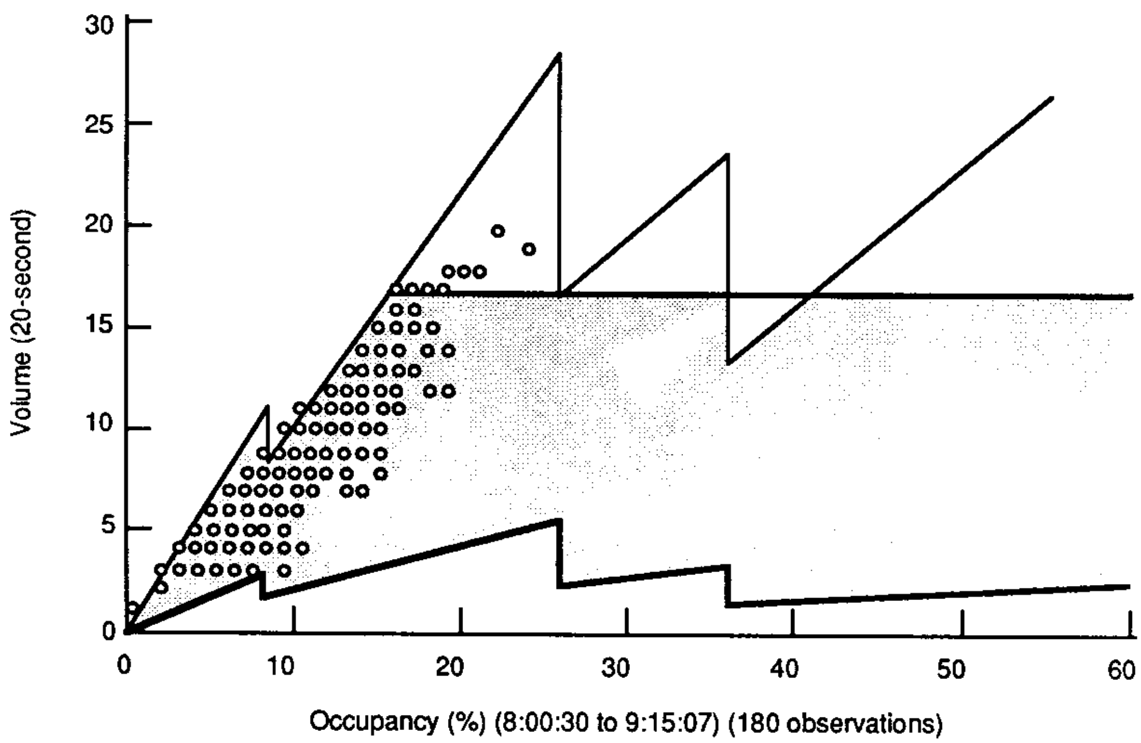


Figure 12. Station 283 Volume and Occupancy Observations with Thresholds (data collected on June 18, 1989)

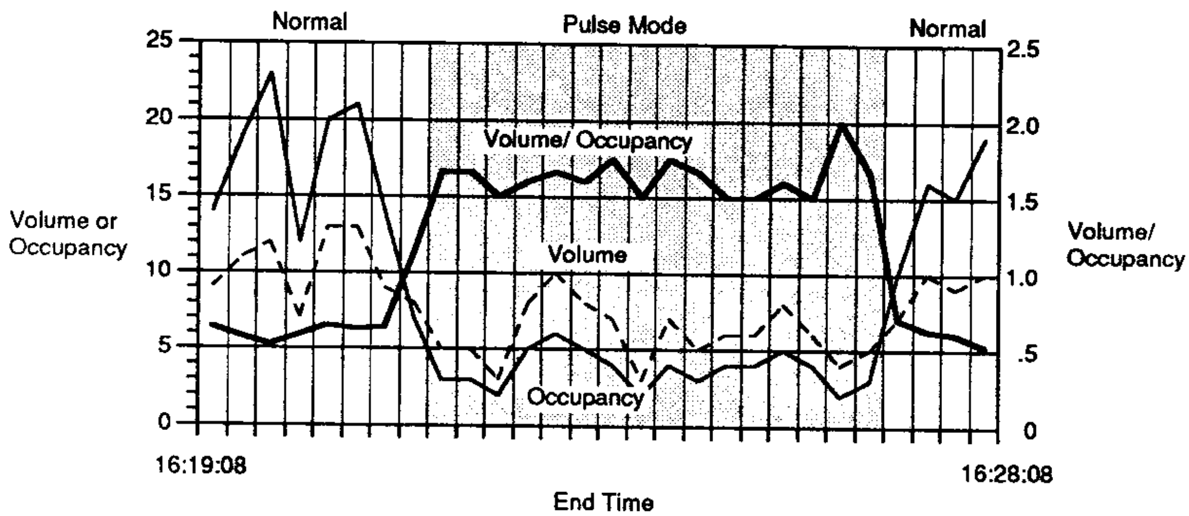


Figure 13. Detector 914 20-second Volume and Occupancy Report (data collected on May 16, 1989)

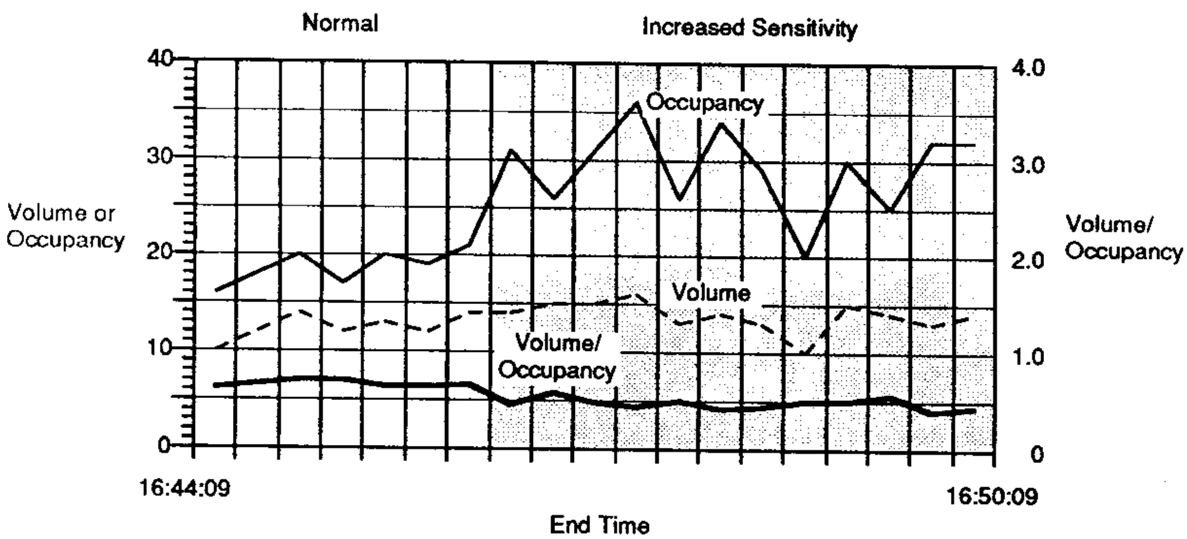


Figure 14. Detector 916 20-second Volume and Occupancy Report (data collected on May 16, 1989)

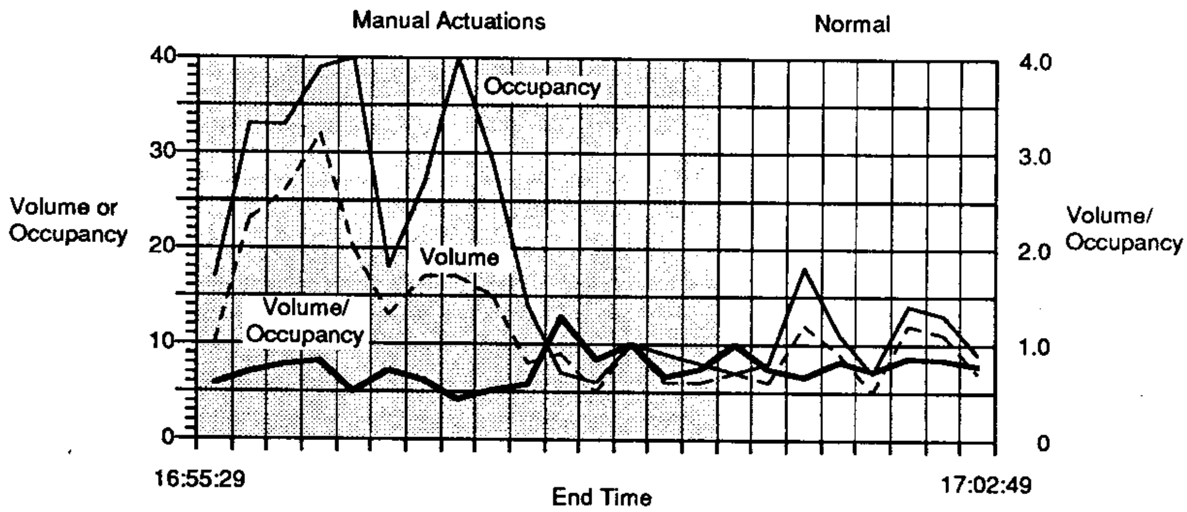


Figure 15. Detector 915 20-second Volume and Occupancy Report (data collected on May 16, 1989)

Table 4. 20-second Volume and Occupancy Report, Detector 914 (data collected on May 16, 1989)

End Time	Volume	Occupancy	Action
16:19:08	9	14	Normal Operation
16:19:28	11	19	"
16:19:48	12	23	"
16:20:08	7	12	
16:20:28	13	20	
16:20:48	13	21	
16:21:08	9	14	
16:21:28	8	7	
16:21:48	5	3	Change Amplifier from presence to pulse
16:22:08	5	3	"
16:22:28	3	2	
16:22:48	8	5	
16:23:08	10	6	
16:23:28	8	5	
16:23:48	7	4	
16:24:08	3	2	
16:24:28	7	4	
16:24:48	5	3	
16:25:08	6	4	
16:25:28	6	4	
16:25:48	8	5	
16:26:08	6	4	
16:26:28	4	2	
16:26:48	5	3	"
16:27:08	7	10	Normal Operation
16:27:28	10	16	
16:27:48	9	15	
16:28:08	10	19	

Table 5. 20-second Volume and Ocupancy Report, Detector 916, May 16, 1989

End Time	Volume (Veh/Period)	Occupancy (%)	Action
16:44:09	10	16	Normal Operation
16:44:29	12	18	"
16:44:49	14	20	
16:45:09	12	17	
16:45:29	13	20	
16:45:49	12	19	
16:46:09	14	21	"
16:46:29	14	31	Increased Sensitivity
16:46:49	15	26	
16:47:09	15	31	
16:47:29	16	36	
16:47:49	13	26	
16:48:09	14	34	
16:48:29	13	29	
16:48:49	10	20	
16:49:09	15	30	
16:49:29	14	25	
16:49:49	13	32	
16:50:09	14	32	"

examination of Figure 6 provides an explanation of why the algorithm did not detect the hanging on malfunction. Detectors that hang on create high occupancies but accurate volumes. The graph shows that given a 20-second volume below 17, only reduced occupancies will create a v/o ratio designated as erroneous by the algorithm. Long pulses created by a detector hanging on are indistinguishable from long pulses caused by traffic congestion. A single v/o ratio cannot differentiate between a detector hanging on and a detector indicating legitimate congestion. A v/o ratio test alone cannot satisfactorily detect this malfunction.

The data generated by calls placed manually through the detector display panel were recognized as unreliable when the simulated 20-second volumes were greater than 17 (Figure 15). It was difficult to know whether many of the manually placed calls represented reasonable representations of traffic. Manual checks of the data provided no indication that the data from Detector 915 on May 16th after 16:58 were unreasonable (Table 6). This test proved to be inconclusive. The results of the test were disregarded.

Table 6. 20-second Volume and Occupancy Report, Detector 915, May 16, 1989

End Time	Volume (Veh/ Period)	Occupancy (%)	Action
16:55:29	10	17	Manual Actions
16:55:49	23	33	"
16:56:09	26	33	
16:56:29	32	39	
16:56:49	20	40	
16:57:09	13	18	"
16:57:29	17	27	
16:57:49	17	40	
16:58:09	15	29	
16:58:29	8	14	
16:58:49	9	7	
16:59:09	5	6	
16:59:29	10	10	
16:59:49	6	9	
17:00:09	6	8	"
17:00:29	7	7	Normal Oper.
17:00:49	6	8	
17:01:09	12	18	
17:01:29	9	11	
17:01:49	5	7	
17:02:09	12	14	
17:02:29	11	13	
17:02:49	7	9	

Table 7. 20-second Volume and Occupancy Report, Detectors 911 and 912, June 15, 1989

	911		912	
End Time	Volume (Veh/ Period)	Occupancy (%)	Volume (Veh/ Period)	Occupancy (%)
8:40:27	3	66	6	62
8:40:47	0	99 *	0	100 *
8:41:07	0	99 *	0	100 *
8:41:27	6	52	9	55
8:41:47	12	17	13	13
8:42:07	13	14	16	15
8:42:27	8	9	11	11
8:42:47	10	9 *	13	13
8:43:07	7	12	12	17
8:43:27	1	98 *	1	99 *
8:43:47	5	81	5	80
8:44:07	11	12	13	12
8:44:27	9	12	13	12
8:44:47	8	10	2	65 *
8:45:07	5	69	4	76
8:45:27	16	19	12	15
8:45:47	7	49	8	48
8:46:07	12	10 *	9	8 *
8:46:27	13	12	14	13
8:46:47	6	5	10	10
8:47:07	10	14	12	10 *
8:47:27	7	7	12	11
8:47:47	8	8	9	8 *

* Data identified by algorithm as bad

The algorithm provided surprisingly few false alarms because of the persistence check used. On June 15th, data from detectors 911 and 912 were flagged as erroneous when no intervention took place (Table 7). Hand checks of the data for detector 911 showed two 20-second periods in succession with 0 volume and 99 percent occupancy. These data points were clearly erroneous, and the algorithm detected the errors. Similarly, two consecutive observations from Detector 912 contained 0 volume and 100 percent occupancy. The algorithm successfully detected these erroneous data points. These two instances demonstrated the algorithm's ability to detect intermittent failures. In these cases, the detectors stuck on for a brief period, then returned to normal operation.

The algorithm only detected false positives on data from detector 912 on June 15th. All of these data points turned out to be very near the data reliability threshold.

The researchers also tried to simulate hanging off malfunctions (short pulses) by decreasing sensitivity levels. The algorithm detected four of five "low sensitivity" observations that should have been identified as erroneous.

The difficulty with simulating short pulses by lowering the amplifier's sensitivity was that the amplifier sensitivity, normally set to a 2 (out of 8), could only be adjusted one level lower. Whether the simulation really produced short pulses in all situations was uncertain. The test results for these simulations were disregarded because of the questionable nature of the simulation.

Table 8 provides the results of testing the error detection algorithm. Because of the questionable nature of the manual actuation and low sensitivity simulations, those results are not presented. Overall, the algorithm performed very well in detecting short pulses caused by changing the amplifier mode from presence to pulse (71 out of 77 instances detected). The algorithm only produced 24 false positive flags out of all the observations (approximately 3,500 total observations). All of the false positives were from the same detector on the same day. On the other hand, the algorithm did not detect long pulse (hanging on) malfunctions caused by high sensitivity tests, even though

Table 8. Algorithm Performance: Erroneous Data Flagging Rate and False Alarms*

			Erroneous Data Flagging Rates Type of Simulated Detector Malfunction		
Date	Station	Detector	"presence to pulse"	"high sensitivity"	Number of False Positive Flags
5/16/89	229	913	0/0	0/0	0
		914	16/16	0/0	0
		915	0/0	0/0	0
		916	0/0	0/12	0
6/15/89	283	781	No Simulations Performed	No Simulations Performed	0
		782			0
		783			0
6/15/89	228	909	0/0	0/0	0
		910	14/17	0/0	0
		911	0/0	0/0	0
		912	0/0	0/0	24 (?)
6/15/89	229	913	6/7	0/0	0
		914	14/15	0/0	0
		915	14/15	0/0	0
		916	7/7	0/3	0

* Based on persistence check (two out of three 20-=second observations).

? = questionable

unreasonably high occupancy resulted. Finally, the algorithm was able to detect intermittent malfunctions due to chattering or stuck on detectors.

Certain characteristics of the 20-second volume and occupancy data used to test the proposed algorithm's data error identification effectiveness deserve discussion. First, the 20-second data tables in the FTMS central computer contained occupancies in tenths of a percent. However, the 20-second occupancies that were used to test the proposed algorithm were whole numbers. Instead of presenting occupancies to the nearest tenth, the data reports that were used to obtain the test data reflected occupancies truncated to whole percentages. Therefore, a number of volume/occupancy ratios that were barely within or outside the volume/occupancy ratio thresholds may have been identified differently. This situation may have accounted for the false alarms from detector 912 mentioned earlier in this chapter. This will not be a problem when implemented because occupancies to the nearest tenth-percent will be used.

Finally, another FTMS's freeway data were used to determine occupancy ranges, g-factor means, and variances. The freeway system in the Seattle area operated under a different speed limit and probably had a different vehicle mix than the one represented in Hall's data. Hall's data were based on median lane traffic with very few trucks in the mix. WSDOT may be able to improve the algorithm by using data (volume, occupancy, and measured speed) collected on the Seattle freeways to develop new volume/occupancy thresholds. This data collection would require the installation of paired speed detectors in the system. The paired detectors would provide several benefits. The data reliability algorithm described here could be improved, not only by using Seattle freeway data, but by expanding to include measured speed in the algorithm. (The long pulse (or hanging on) malfunction could probably be detected using measured speed and comparing it to estimated speed.) In addition, measured speed could supply data for the motorist information system and lead to improved incident detection and ramp metering algorithms.

However, the methodology used in this research to detect erroneous detector data performed quite well, and indications were that the Canadian data fit Seattle traffic conditions rather well.

CHAPTER 5
FREEWAY DATABASE REQUIREMENTS

The researchers interviewed potential users of the FTMS data to determine their needs. This discussion focuses on TSMC users, university researchers, and outside users.

TSMC

As noted earlier, as part of its I-90 project, the WSDOT plans to replace the TSMC's computer with a new, more powerful system. Presently, the TSMC is working directly with a consultant to define the new system. Therefore, the research team did not recommend a structure to meet TSMC data needs, but rather one to meet the TSMC concerns about outside use. TSMC engineers expressed concern over personnel and other resource demands of the database. They prefer that data access and processing be as automated as possible. Thus, a primary goal of the researchers was to minimize the amount of effort TSMC personnel must expend in responding to data requests.

UNIVERSITY RESEARCHERS

Researchers at the UW have made fairly intensive use of freeway data on the tape archive. (16, 17, 18) Researchers have used the freeway data primarily for research to improve and evaluate WSDOT's freeway management system. The most common use has been to construct time-series of data from one or a few stations across several months. Such access requires relatively large amounts of CPU time and I/O resources, but it is easily accomplished on a multiuser mainframe such as the CYBER. Similarly intensive use of the TSMC's limited minicomputer would probably not be feasible.

Because both volume and lane occupancy data are needed to estimate traffic speed, the lack of lane occupancy data in the archive has proved to be a handicap in several research projects. To date, researchers seeking to evaluate changes in travel time or level of service have had to use the microfiche records to obtain lane occupancy data.

Until lane occupancy is included in the tape archive, research that attempts to assess changes in level of service or travel time will be difficult to perform.

In the past year, two WSDOT sponsored research efforts aimed at improving the operation of the I-5 freeway system have required volume and lane occupancy data collected over short (20-second or 1-minute) intervals. One project has investigated short-term forecasting of freeway bottlenecks with the intention of improving the level of service provided by peak period ramp metering. (19) The other effort was the detector error identification portion of this project. Personnel at the TSMC had to schedule special data collection reports to allow the researchers to obtain this short interval data. The needed data were stored on tape as they were collected. Students from the University traveled to the TSMC to pick up the data tapes and take them to the University. At the University, a mainframe computer read the data from the tapes. The data were manually checked for accuracy. If any problems with the data surfaced, the researchers repeated the whole process of scheduling the reports and collecting data tapes. The time involved to collect critical data for analysis caused several delays in the optimal schedules for the projects.

Although this data source proved very useful, the need to burden TSMC personnel with its collection, the relatively limited amount of data that could be collected, the logistical problems in transferring data tapes from the TSMC to the University computer, and the vulnerability of these reports to being overridden by higher priority uses of the TSMC's computer limited the efficiency of collecting data and created delays in critical stages of the research.

OUTSIDE USERS

Outside users of freeway data are all users except TSMC personnel and university researchers. This category includes other WSDOT users and transportation professionals in agencies such as Puget Sound Council of Governments (PSCOG). The researchers conducted a survey of local transportation professionals interested in using this database. The appendix to this report describes the survey. The primary use of freeway data of interest to outside users would be to create summary volume information, such as ADT, AWDT, morning and afternoon peak hour volumes, and peak hour factors. The users were reluctant to specify beforehand the locations or time periods for which they might want this information. They would prefer to have it generated easily on request. They expressed little interest in data collected over shorter time intervals, in data in time-series form, or in lane occupancy data. They expressed a definite reluctance to pay the UW for access to such information, or to invest other resources to obtain this information from the existing archive at the UW. Only WSDOT personnel in Olympia expressed interest in dial-up access to the data. The other users would prefer to request data in report form and have it mailed to them.

Users from the UW, from the Olympia offices of WSDOT, and from PSCOG expressed a consistent opinion on the treatment of erroneous data. If the data are clearly erroneous, users would prefer to have them deleted from the database and replaced with a missing data flag. However, if the data are suspect, users would prefer that they be able to recover these data, with a notation that they might be erroneous. Generally, the users would prefer to make their own decisions as to the suitability of suspect data, rather than have this decision be automated.

RELATION TO OTHER SURVEYS AND GUIDES

In order to be as consistent as possible with other data recommendations, the researchers reviewed the WSDOT's Statewide Highway Data Rationalization Study and FHWA's Traffic Monitoring Guide to determine whether there was any overlap between this research and those resources.

Statewide Highway Data Rationalization Study

The Statewide Highway Data Rationalization Study (DRS) performed an in-depth evaluation of WSDOT's highway data development and analysis activities and developed procedures and recommendations for a streamlined highway data collection program. The study included a survey of potential data users. The primary information that the TSMC system can provide these users comprises volume data. The study pointed out that most of those surveyed desired Annual Average Daily Traffic (AADT). The rest of the volume needs could be obtained from hourly distribution of traffic. These requirements coincide with the results of the of the informal survey conducted as part of this research project, mentioned in the previous section. In essence, each data station in the TSMC system could act as a permanent traffic recorder. The database recommended in the next chapter would meet these needs.

The Data Rationalization Study identified two other types of data worth mentioning: speed data and vehicle classifications. The TSMC system is not collecting speed data on a large scale. (There are two data stations with speed detection.) However, as mentioned in Chapter 4 and in the recommendations section, the research team recommends installation of speed detection throughout the system, as the budget allows. As the speed loops are installed, any needs for speed measurements on the Seattle freeway system could be met. Vehicle classifications are not needed in any manner in the current system. However, as speed loops are installed, the system would be capable of providing "four-bin" vehicle classification. The desired level of detail for vehicle classification is in the "13-bin" format. Therefore, the TSMC system could only provide limited or interim vehicle classification data.

Traffic Monitoring Guide

The Federal Highway Administration's (FHWA) Traffic Monitoring Guide primarily covers data needed by the Highway Performance Management System (HPMS): traffic volume data, vehicle classification data, and truck weight data. The

TSMC system has no capability to collect truck weight data. As mentioned above, with the addition of speed detectors, the system would have four-bin vehicle classification abilities. However, the HPMS system should use 13-bin vehicle classification data. Therefore, as stated above, the TSMC system could only provide limited use for vehicle classification. The primary volume data the HPMS system needs are AADT and hourly distributions. The TSMC system is capable of supplying these data. This data need is consistent with the needs of the users surveyed in this research.

SUMMARY OF USES

The researchers identified three different uses of freeway data, and two user classes. The three uses were as follows:

(1) Time series of volume and lane occupancy generated from archived data. Researchers at the University of Washington require these data for use in WSDOT sponsored research.

(2) Data collected over short (20-second or 1-minute) intervals for use in traffic flow and forecasting research. The TSMC needs these data to analyze and evaluate the performance of the freeway management system. UW researchers also require data in this form for use in WSDOT sponsored research.

(3) Summary statistics of volume data, such ADT, AWDT, peak hour volumes, and peak hour factors. TSMC personnel, other WSDOT personnel, and personnel from other transportation planning agencies need these data. The data are also needed by the Highway Performance Monitoring System (HPMS).

The user classes identified were as follows:

(1) Transportation researchers at the UW. These users desire data for numerous studies and generally desire a minimum of processing by

TSMC. They have so far preferred data in raw form and have been willing and able to edit and format it to suit their needs.

(2) Transportation planning agencies. These users are not interested in raw data but rather volume summary information. They prefer to be able to obtain this information on demand, at low cost, and in as painless a manner as possible.

The need for speed and vehicle classification data was mentioned in the previous section. However, the current system does not have the capability to collect these data. If the WSDOT decided to install speed detectors, then the system would be able to collect speed data and four-bin vehicle classification data, and these data could be added to the uses listed above.

CHAPTER 6

FREEWAY DATABASE RECOMMENDATIONS

As part of the I-90 project, the TSMC plans to purchase a new computer system that will both prepare and store archived data and run the ramp-metering system. Current plans call for tape storage of 5-minute volume and lane occupancy data for each detector in the system, and for approximately the most recent year's 5-minute volume and occupancy data to be stored on disk. Assuming that TSMC data needs will be satisfied in the design of the new system, the major questions yet to be answered involve serving users from the UW and outside agencies. The first issue addressed was how to flag erroneous data. The researchers proposed a generic configuration to satisfy all of the major requirements of the database. After presentation of the recommended data flagging methods, this chapter discusses the proposed database configuration and some of the losses involved in eliminating components of this configuration.

FLAGGING ERRONEOUS DATA

Once an error detection algorithm has been implemented, WSDOT must decide how to encode this new information into the database. As noted earlier, users would prefer that the data be classified as reliable, erroneous, or suspect. They also would prefer to be able to recover the actual values of suspect data from the database. In the long term (after the upgrade of the TSMC's computer system) the actual details of the coding and recovery of this information will be left to the TSMC and its consultant; however, some general recommendations are included here. For the near term (using the TSMC's existing computer system) three-way coding of data is impossible without a major restructuring of the existing database. Restructuring is viewed as infeasible, especially since any work would be made obsolete shortly by the new system. However, data can be coded as erroneous or reliable. Discussion with WSDOT personnel produced the following protocol for deciding when a 5-minute value should be coded as erroneous.

(1) Erroneous 5-minute volumes will be coded as 255 in the database. Reliable data will be entered as they are.

(2) In any given minute, if data for one 20-second interval are determined to be suspect, the 1-minute total will not be modified. For one erroneous 20-second data period in a minute, the system will replace the volume and occupancy with the average of the data from the two previous 20-second periods. However, if data for two 20-second intervals in one minute are determined to be erroneous or suspect, then the 1-minute and corresponding 5-minute data will be coded as erroneous.

(3) A counter will be kept of the erroneous and suspect 20-second data for the current 5-minute period. If the counter exceeds an operator defined threshold (on the order of 5), then the 5-minute data will be considered erroneous, and the 5-minute volume will be set to 255. The 5-minute occupancy will be set to a -1.

In the long term, the research team recommends that the following general capabilities be included in the database system.

(1) Analyze data integrity on the basis of 20-second data buffers. Use this basic data check as the basis for determining reliability of 1-minute, 5-minute, and hourly data, both occupancy and volume.

(2) Flag suspect data in occupancy and volume buffers. Volume and occupancy may be used independently. Therefore, it is important that the data in both types of buffer be flagged. Also, error detection algorithms may detect erroneous occupancy only, while volume is reliable. Designers should account for this situation in the new system.

(3) Remove clearly erroneous data from the 20-second, 1-minute, and 5-minute volume and occupancy data buffers. Suspect data should be flagged but remain in the buffers. To avoid confusion, clearly erroneous

data must be removed and replaced with an indication that the data are erroneous and missing.

(4) Use user-defined and operator selectable variables to determine the thresholds of suspect data periods that indicate erroneous data. If suspect data persist beyond a threshold, they should be considered erroneous. The threshold should be set on the basis of further analysis.

(5) Structure the database to facilitate data replacement algorithms that may be developed from future research projects. A project that begins in the latter half of 1989 will investigate, and may develop, algorithms that will estimate values of volume and occupancy when erroneous data are detected. Provisions for incorporating this type of algorithm should be included in the database system.

(6) Printed reports and reports written to transferrable media must give clear indications of suspect and erroneous data. The system must also have the ability to discard days with erroneous data from any automated statistic routines. Statistics that use suspect data should be flagged, and an indication of the number of suspect data used in the statistic should be included.

FUTURE COMPUTER CONFIGURATION AT TSMC

The configuration should have the following components:

(1) An off-line archive of 5-minute volume and lane occupancy data maintained at the TSMC. This archive would contain historical data collected by the system and would most economically be stored on magnetic tape. The amount of historical data to be stored should be addressed by the system designers and the TSMC staff. Although on occasion it might be useful to continue to store data from the initiation of

the system, there would be a practical limit to the amount of raw 5-minute data stored. Consideration should be given to storing summary statistics only for data more than 10 years old.

(2) An on-line archive of the most recent year's 5-minute volume and occupancy data maintained on disk at the TSMC.

(3) A copy of the off-line archive maintained on magnetic tape at the UW, along with the software necessary to satisfy most UW research needs. The University researchers could maintain a full library of all the historical data collected from the system.

(4) A powerful microcomputer (such as a SUN 4/80) at the TSMC with access to the on-line (most recent year's) archive. The WSDOT should consider software for this microcomputer that would allow a user to select a set of freeway locations and range of dates and then compute summary statistics from data in the on-line archive. The alternative would be to require the user to have this software and allow the user to download the raw data required and compute the summary statistics on the user's computer. Since much of these data would be useful to the TSMC for evaluations of the system, it is recommended that this ability be programmed into the TSMC computer. The summary statistics should include, but not necessarily be limited to, ADT, AWDT, morning and afternoon average peak hour volumes, and average peak hour factors. The microcomputer should contain a direct connection to WSDOT headquarters and also be accessible to other agencies and the UW via dial-up modem. The user should also be able to specify whether the program's output should be downloaded or written to some transportable storage medium for later pickup.

(5) A capability for outside users to schedule special data collection efforts (i.e., at the 20-second or 1-minute timescale) on the TSMC's mainframe directly via dial-up modem rather than through TSMC personnel. Again, the user should have the option of downloading these data or writing them to transportable storage. This capability would provide better service to the user while minimizing TSMC staff time.

If the WSDOT decides to install speed detectors in the system, as the research team recommends, the database in the new computer system should be designed to handle speed and four-bin vehicle classification data.

ANALYSIS OF COMPONENT NECESSITY

Components (1) and (2) above are already planned as part of the TSMC's new computer system, so their elimination will not be discussed. Component (3), the tape archive at the UW, is included because it is relatively inexpensive and would allow UW researchers to continue tailoring their data retrieval and analysis system to their own needs. Elimination of component (3) would mean that UW researchers would have to obtain data from the TSMC's archive via the TSMC's computer. This process would needlessly take up computer time on the TSMC computer. The full cost of the data storage at the University should be borne by the University itself.

Option (4) serves the same purpose as option (3); namely, it removes a major demand of computer and personnel time from the TSMC's main computer system. Elimination of option (4) would mean that outside users would have to obtain summary statistics from either the TSMC's mainframe or from the UW tape archive. Past experience has shown that WSDOT headquarters is not interested in relying on the UW for its data needs, while reliance on the TSMC's mainframe could eventually lead to priority conflicts similar to those experienced on the current system. Elimination of option (4) would also place a major data collection requirement on TSMC personnel.

Elimination of option (5) would reproduce the current status quo, in which UW (or other) researchers need to contact TSMC personnel to obtain special data collection. The current system requires too much use of TSMC personnel. Parties on both sides perceive the current system as time consuming and awkward.

SUMMARY OF NEW DATABASE CONFIGURATION

The main strength of the above configuration is that it would provide a quasi-independent system for each major user class. In other words, the demands of one user group would not greatly interfere with the needs of others, while substantial backup capability would be available. The major new features of this configuration are option (3), an independent microcomputer for generating summary statistics on request, and option (5), software to allow outside users to schedule special data collection efforts.

CHAPTER 7

APPLICATION AND IMPLEMENTATION

Implementation of the results of this research will fall into two categories. The first will involve programing the error detection and flagging procedures developed for this project. The second aspect of implementation will deal with the future implementation of the longer term recommendations contained in this report. These recommendations deal with the database configuration of the new TSMC computer and the error flagging techniques to be used in that system. Implementation of these recommendations will be undertaken during the design of the new TSMC computer system and will be dependent on the overall architecture of that system. This chapter focuses on the implementation of the error detection and flagging procedures in the existing system.

Data in the WSDOT FTMS are used both for control and analysis purposes. The detection of erroneous data must be accounted for and reflected in the data used for both purposes. The historical archives on tape, as well as the data tables resident on disk, are accessed for analysis purposes, while only the data buffers in system memory are utilized for control.

The first thing to consider for implementation is that the algorithm is valid for mainline detectors only. Traffic in the HOV lanes and on ramps have different speed-occupancy-volume profiles than traffic on the mainline. Whether this algorithm could be adapted to ramp detectors is questionable because of the influence of traffic signals and ramp meters and the unique acceleration and deceleration maneuvers prevalent on ramps. WSDOT could possibly apply the algorithm to HOV lanes, but it would have to investigate different thresholds because of the unique vehicle mix in HOV lanes. Therefore, the FTMS system must differentiate between mainline detectors and other detectors and only apply the algorithm to the mainline detectors.

With the implementation of the new error detection algorithm, some data will clearly be erroneous and some will only be suspect. Data from chattering and stuck detectors will be considered erroneous. Data identified by the volume/occupancy thresholds will be considered suspect. The system will have to keep track of the difference between erroneous and suspect data and treat the data differently on that basis. WSDOT will also have to provide a threshold beyond which suspect data are considered erroneous. (For example, if data in more than five 20-second periods are suspect in any given 5-minute period, the data for the 5-minute period are considered erroneous.) In the WSDOT system, this concept is more important for analysis purposes than for control purposes, since all control decisions are based on 1-minute data.

The current WSDOT FTMS software provides alternative logic for malfunctioning detectors and stations. (Additional development and improvement of this alternative logic, including investigation of replacing the erroneous data, will be part of a research effort to begin in autumn 1989.) The new algorithm will be implemented in this same environment and will interact with the control logic in the same manner that the existing error detection routines do. Detectors that the algorithm determines to be malfunctioning will be identified in the failed detector array. As the control algorithms extract data from the data buffers, the failed detector array will be checked. If the detector from which the data came has failed, the control algorithm will jump to the routine for failed detectors.

Suspect data will contribute to control decisions until the system determines, on the basis of the threshold values chosen, that the detectors supplying the data are malfunctioning.

Dealing with suspect and erroneous data in the 5-minute data tables that are the basis for nearly all analysis will be slightly more complex. Users of the historical data would prefer that the data be classified as reliable, suspect, or erroneous in the database. They also would prefer to be able to extract the suspect data from the database. Because of the structure of the existing database and the limitations of resources in the current computer system, this three-way data coding is not possible. As mentioned previously, this research recommends that this three-way data coding be implemented in the new TSMC computer system. Therefore, the new algorithm will be implemented in the current system with coding that identifies data simply as erroneous or reliable. Suspect data will remain in the database. However, the incidence of suspect data will be monitored, and if threshold values are reached, the data will be coded as erroneous. Erroneous data will be eliminated from the database and replaced with an erroneous data flag. The erroneous data flag for volume will be 255 and for occupancy will be -1.

As stated earlier in this section, suspect data are data identified as being outside the volume/occupancy thresholds of the new error detection algorithm. If two out of three 20-second periods in a minute yield suspect data for a detector, the 1-minute data for the detector will be considered erroneous and replaced with the flag. If any 1-minute period in five contains erroneous data for a detector, then the 5-minute data for that detector will be considered erroneous and replaced. The system will also keep track of the number of 20-second periods in 5 minutes that yield suspect data for a detector. If the suspect data counter reaches a program variable (initially set to five) in a 5-minute period for a detector, the 5-minute data for that detector will be considered erroneous and replaced. Finally, an hour with one 5-minute period of erroneous data for a detector will lead to the hour's data being considered erroneous. Generated reports will print negative numbers for erroneous data. Erroneous data will not be considered in the calculation of totals and averages.

These general logic guidelines must be programmed in the software for the TSMC computer system. Several tasks and routines within those tasks must be modified. Modifications are needed to the software of both computers within the TSMC computer system. The error detection algorithm itself should reside in both computers and act directly on the data collected from the field by the respective computers.

In the VDS computer, the error detection algorithm would reside in the 20-second task (TWTSEC). Several routines within the TWTSEC would have to be modified, including ACDIAG, MOVAVE, and RTTRAF. These routines would identify 20-second errors, flag the 20-second and 1-minute data, and set error bits in the detector failure array. The failure handling task (FALTSK) would have to be modified to generate alarms for the new error detection algorithm. The 1-minute task (ONEMIN) would have to be modified to determine 5-minute data errors and flag the 5-minute data.

In the CTCM computer, MIOMST would have to be modified to include the data error detection algorithm. It would flag the 20-second data and set detector error bits. The 1-minute task (MINUTE) would flag the 1-minute data. The failure handling task (FAILPR) would generate alarm messages based on detector errors.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The developed macroscopic inductive loop detector reliability algorithm consists of a 20-second volume/occupancy threshold test, a 20-second volume threshold test, and a 5-minute occupancy threshold test. The primary purpose of developing a new algorithm was to detect intermittent failures and short pulses with few false alarms (false positives).

The algorithm developed proved to produce very few false alarms when tested. It reliably identified short pulse (hanging off) malfunctions during simulation tests. It also identified actual malfunctioning detectors at two sites over the course of the project. Because the algorithm was based on 20-second data rather than on 5-minute data, as in the current macroscopic error detection routines, it will detect intermittent failures more often and more reliably. However, the algorithm does not detect long pulse (hanging on) malfunctions.

The thresholds for the algorithm were derived from data from the Province of Ontario and tested at several locations in the Seattle system using actual data. The Canadian data provided thresholds that fit traffic conditions in the Seattle system very closely.

The algorithm will provide a relatively simple and affordable improvement to the WSDOT's existing freeway data screening methods. The WSDOT can easily implement the algorithm system-wide for its mainline loop detectors because it is resident in the central computer, and the field units do not need software modifications or calibration. Freeway incidents and on- and off-ramp proximity to detector stations do not compromise the algorithm's effectiveness.

This algorithm allows a single detector system to use a surrogate of speed to screen data. This ability adds a dimension to detector error checking that has not been utilized in the past.

It is important to note that the algorithm is valid for mainline detectors only. Traffic in the HOV lanes, on collector-distributor roadways, and on ramps have different speed-occupancy-volume profiles than traffic on the mainline. Therefore, the FTMS system must differentiate between mainline detectors and other detectors and only apply the algorithm to the mainline detectors.

The existing database consists of tape archives of 5-minute volume data maintained at both the TSMC and the UW. Limited lane occupancy data are maintained on microfiche at the TSMC, and some limited capability of collecting data on-line also exists. The three major groups of data users, TSMC personnel, UW researchers, and transportation planners (including WSDOT personnel not at the TSMC) are not as well served by the existing database as they desire. In the existing system, erroneous data are not flagged in the database. Analysis accuracy and personnel requirements suffer as a result.

RECOMMENDATIONS

Several recommendations can be made on the basis of this research. First, the new error detection algorithm should be implemented in WSDOT's electronic surveillance system. The algorithm detects errors that are not detected in the current system and has a low false alarm rate.

Additional simulations should be undertaken to further substantiate the conclusions given. A review of the test data and analysis suggests that more presence to pulse and high sensitivity tests are necessary to provide stronger evidence of the algorithm's success or failure in identifying hanging malfunctions. If the manual actuation simulation is used again to simulate detector chatter, detailed descriptions of the actions taken and the equipment's response to those actions must be provided. Careful consideration will have to be given to the type of malfunction the manual actuations would simulate. New test data analysis should also be performed using data that represent occupancy to the nearest tenth percent.

Because the algorithm's volume/occupancy ratio thresholds were developed with data from a different system, adjustments of the thresholds should be investigated in order to calibrate the algorithm to the WSDOT system. The research indicated a good fit of the Canadian data to traffic conditions in the Seattle system. Even so, fine tuning of the thresholds should be investigated. As an interim measure, the volume/occupancy thresholds can be raised or lowered until an acceptable combination of false alarms, false negatives, and invalid loop detector data identification ability is achieved. This trial and error procedure is not optimal, and an investigation similar to Hall and Persaud's to discover the g-factor and occupancy relationship that is based on the traffic flow behavior is recommended. Such an investigation would require the installation of paired speed loops at locations within the system.

The researchers recommend the installation of paired speed detectors throughout the system as the budget allows. This expenditure would provide additional benefits by supplying measured speed for improved error detection, improved data collection for motorist information systems, improved incident detection algorithms, and perhaps improved ramp metering algorithms.

WSDOT should investigate the use of additional occupancy ranges in the algorithm to improve the algorithm's performance. Figure 6 indicates that there are relatively severe discontinuities at the occupancy range boundaries. These discontinuities can be reduced, providing more accurate error detection, with the use of more occupancy ranges.

The proposed algorithm might be improved if it were location specific rather than general for the entire system. Grade, for instance, affects the g-factor value at a particular occupancy. Therefore, the algorithm's performance could be improved if three sets of thresholds (positive grade, negative grade, and flat) were available instead of one. Basing the thresholds on grade would enable the volume/occupancy thresholds to be more focused or restrictive. The ideal improvement would be to determine volume/occupancy thresholds for each detector station. However, calibrating each detector station would be very expensive and time-consuming and probably could not be justified on the basis of improved performance.

The subject of detecting errors from detector systems deserves further investigation. Although the algorithm developed here adds capability to detect some errors, errors that occur during congested and heavily congested traffic conditions have a high probability of remaining undetected. Research is needed to determine how errors, especially intermittent errors, can be detected during these conditions when accurate detector data are most critical for control purposes. In-depth time series analysis of detector data and the notion of lane sympathy deserve investigation for improved error detection routines.

With the implementation of the new error detection algorithm, some data will clearly be erroneous and some will only be suspect. Data from chattering and stuck detectors should be considered erroneous. Data identified by the volume/occupancy thresholds should be considered suspect. WSDOT should provide a threshold beyond which suspect data are considered erroneous. (For example, if data in more than five 20-second periods are suspect in any given 5-minute period, the data for the 5-minute period are considered erroneous.)

A related recommendation is that the future database should be able to classify data as reliable, erroneous, or suspect and that users should be able to recover the actual values of suspect data from the archive. For the existing system, data should be classified as reliable or erroneous. The decision of how to handle erroneous data is detailed in the body of this report.

In conjunction with the TSMC's computer upgrade, the UW should continue to maintain a computer tape archive of volume and lane occupancy data, and the TSMC should obtain a microcomputer that will prepare summary statistic information from an on-line archive of about one year's length. Furthermore, this microcomputer should be accessible by selected users outside the TSMC via dial-up modem in order to reduce the amount of TSMC staff time required to process data requests and to improve the availability of the freeway data. The computer should be capable of generating and printing summary information without the direct intervention of TSMC personnel. Such capability would give each major user group relatively independent access to the type of data it needs while also providing substantial backup. (If WSDOT decides to install speed detectors in the system, the microcomputer database should be designed to handle speed and four bin vehicle classification data.)

Finally, nationwide networks such as BITNET, INTERNET, NSFNET, and in the transportation field, AASHTO's network, currently provide at least a rudimentary capability for data and information exchange, and the ease of use and power of these networks should continue to expand as time passes. In contrast, in the Puget Sound region a number of different institutions, all ostensibly dedicated to the goal of serving the traveling public, all staffed by professionals who share an ability to discuss and analyze transportation issues within a common framework, are yet unable to easily share data. Therefore, this report should be viewed as only a first step toward a larger goal of a regionwide transportation information network.

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APPENDIX A

SURVEY OF OUTSIDE USER NEEDS

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SURVEY OF OUTSIDE USER NEEDS

RESEARCH DESIGN

To determine the existing and potential needs of a selected few users, a survey questionnaire was prepared and distributed. The users questioned were selected rather than chosen at random for the reasons that the state owned freeway database would be useful only to the agencies selected and also would not be widely circulated. Other agencies or individuals who use freeway data obtain it from the selected users in different forms and less frequently. Moreover, the survey was conducted informally so that users could get an idea of the database's applicability to their purposes.

Informal telephone calls were made initially to the selected agencies to determine whether they were interested in access to the database. A brief account of the form of the database and its coverage was given to them so that they could form an idea of its applicability. Later, mail-back questionnaires were sent. The agencies/persons to whom the questionnaires were mailed were as follows:

(a) King County Engineer

(b) Metro

(c) City of Lynnwood

(d) WSDOT, Olympia

(e) PSCOG

Telephone calls made to Snohomish County and the City of Seattle yielded the information that these agencies did not need to receive a questionnaire. They preferred to state their views and needs over the telephone.

RESULTS

City of Seattle

The Traffic Engineer for the City of Seattle felt that data from arterial streets are more useful than freeway data. Hence he is not using the database and does not foresee regular use in the future. However, he mentioned that developers and private consultants may request the data from the city. He also mentioned that ramp volumes are required once a year for the city, as and where data are available. Such data would be useful to the city in analyzing intersections that meet freeway off-ramps. Also, the city maintains monthly volume accounts of crossings at the Ship Canal bridge and the West Seattle freeway in the Duwamish area.

Snohomish County

The Snohomish county transportation planning department does not have a need to obtain the freeway data from the TSMC directly. Requirements for summary statistics (its main requirement) regarding freeway systems operations are met by data obtained from the PSCOG.

City of Lynnwood

The Traffic Engineer for the City of Lynnwood mentioned that he does not use the freeway database. However, he may need to use it in the future. He mentioned that the City of Lynnwood requires freeway data on a quarterly basis. It is interested in the average weekday traffic from each quarter, namely January-March, April-June, July-September, and October-December. Ramp roadway reports are desirable. Also ADT, AWDT, weekend reports, and 24-hour reports with a.m. and p.m. peaks are required. Lynnwood currently monitors stations at 44th W and 196th SW on I-5. Lynnwood also needs summary statistics, such as mean, median, standard deviation, and maximum and minimum values of the measures involved. The Traffic Engineer felt that a dial-up modem would not be needed for him to log on to the central system at the TSMC; he said that mailed reports are a satisfactory and reliable means of obtaining the required information. Lynnwood also is not particularly concerned about flagging data as erroneous or suspect. It prefers to trust the discretion of the project manager at the TSMC to leave out any erroneous data that are obvious outliers.

Lynnwood does need measures of effectiveness such as LOS, speed, and density. Lynnwood needs historical data that are only a few months old.

Department of Transportation, Olympia

The Department of Transportation is interested in representative samples of ADTs, monthly statistics of lane occupancy and volume, maximum statistics of lane occupancy and volume, and ramp roadway reports. It is also interested in peak hourly statistics and top 5 p.m. peaks scheduled as special requests by month, day, time, and site. Its need for peak hour statistics on daily HOV volumes is increasing and will be an important future consideration. At one time it will need to schedule special requests for 2-3 days of peak hour HOV statistics that can be retrieved from microfiche. It would like to have the added capability to pull data from the loops on reversible lanes and add them in the appropriate directions. Also, it looks for continuous flow on the lanes in terms of volumes and occupancy, though the latter is not as important. It wants data to be flagged as suspect or erroneous; however, it would like to retain data that are flagged as suspect, though possibly on a separate file. WSDOT suggests that 12 complete tapes of the most recent historical data be stored, on the assumption that one tape stores about a month of data. As part of federal requests it is engaged in preparing LOS, and hence it would like current LOS as well as future LOSs to be appended to the database. WSDOT expressed interest in setting up a dial-up modem. However, it also suggested that a facility be made available for copying data onto floppy disks.

Puget Sound Council of Governments

The PSCOG is primarily interested in ADTs, hourly volumes, and peak hour factors for various stations on the freeways. The COG is also interested in obtaining ramp reports. As for historical data, it suggests that the most recent year's data be stored. It does not see any particular need for lane occupancy. It is not interested in a dial-up modem, since it can afford to wait for a mailed paper report; however, it would not discourage the establishment of one. It is also interested in obtaining monthly traffic reports with volume trends. Also, PSCOG would like to have peak hour distributions clearly stated.

Metro

Metro does not currently use the TSMC freeway database. However, the Metro representative expressed hope that the data might prove to be helpful in some way in the future, though he is not sure how. Metro is more interested in arterial counts of lane volumes and LOSs in terms of bus headways. Moreover, what interests it is the possible applicability of this database in the form of HOV volume counts. It does not find lane occupancy useful in any way.

CONCLUSIONS

The conclusions of this survey are as follows:

(1) Most of the surveyed users expressed a hope that the freeway database would be expanded into a freeway and arterial database.

(2) The respondents commonly felt the finest level of gradation they required consisted of statistics and 15-minute volumes. The summary statistics should include mean, median, maximum, minimum, and standard deviation of the measures involved. Also, peak hour statistics (a.m. and p.m.) are major requirements.

(3) An important feature for a few respondents, such as WSDOT and Metro, was HOV volume counts.

(4) Flagging data as erroneous or suspect was not really a concern of most of the respondents except WSDOT. The choice of retaining erroneous or

suspect data in the reports should be left to the project manager at the TSMC.

(5) A dial-up modem was felt to be a helpful means of accessing the database from the WSDOT's point of view only. Other agencies did not feel they needed it because they probably have enough lead time in obtaining paper reports mailed to them.

(6) WSDOT felt that floppy disks are a good storage source. Other agencies, such as the City of Lynnwood, appreciated the idea but did not voluntarily suggest it.

(7) A few agencies such as the WSDOT and PSCOG felt that the most recent year of data should be kept as historical data.

(8) A facility in the database to add reversible lane counts in the appropriate direction might be desirable.