Chapter 5
DATA COLLECTION

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CHAPTER 5 - DATA COLLECTION

5-1.00 INTRODUCTION

Traffic data is collected both by offices directly involved in research, and by other offices which may not be directly connected with research or even with traffic engineering. Traffic data is demanded for design, operations, maintenance, programming, forecasting and other functions, as well as by politicians and political units for their own information and use. In many cases personnel involved in actual data collection require specific guidance in collection methodology and basic data handling. This chapter provides such guidance.

5-1.01 Purpose

Traffic data collection provides the basis for identifying problems, confirming earlier hypotheses, quantifying the impact of changes, and determining the nature or magnitude of needed improvements. Data adequacy and reliability, which are absolutely essential to any traffic engineering study, require careful, standardized collection and analysis to ensure valid interpretation and comparability. The purpose of this chapter is to outline standards for traffic data collection.

5-1.02 Scope

This chapter describes the manner in which basic traffic engineering data are obtained and recorded, as well as basic calculations and analysis techniques. The following subjects are addressed for each type of traffic engineering data:

1. Equipment used
2. Field data collection
3. Forms used
4. Sample size required
5. Computations
6. Uses of data

In addition, other subjects are included for some types of data as required. None of the subjects are meant to be covered exhaustively. Special case uses may be made of data, new equipment may come out, forms may be modified to include additional desired information, sample sizes may be adjusted for greater or less precision etc. This chapter provides a foundation for both standard and ad hoc studies.

5-1.03 Chapter Organization

Data collection techniques for 16 basic data types are discussed in this chapter. These are listed in the Table of Contents. References given at the end of this chapter provide for a much more thorough, definitive review of the studies covered in this chapter, and one or more of them should be utilized as appropriate, especially in the case of a particularly extensive or critical study.

5-2.00 GLOSSARY

The definitions given below were selected either because, 1. The terms are used elsewhere in this chapter, or 2. The terms are key to a basic understanding of data acquisition and analysis. In the latter case, a grasp of such concepts as randomness, correlation, and normality will greatly aid even those who merely use research information provided by others. With the proliferation of statistical calculators and computer software, it has become increasingly common to find mathematically correct procedures inappropriately applied to data due to a lack of understanding of basic statistical concepts. This emphasizes the general need to have research studies overseen by personnel trained in research and associated statistical techniques. For those without appropriate training, it is intended that the definitions listed here, as well as the text throughout this chapter, will give them a foundation in the general concepts and execution of traffic research. With this goal in mind, the following definitions include not only simple descriptions, but additional comments and examples as required to provide a working understanding of each concept.

Analysis of Variance (ANOVA) - A statistical technique generally used to assess whether three or more sample means were based on samples drawn from the same population. For example, the researcher may obtain average speeds of motorcycle, automobile, and pickup drivers at a roadway location.

The average speed of each group is somewhat different from that of the others. Are the average speeds for these groups really different, or are these differences just due to chance? ANOVA answers this question by comparing how much the speeds vary in each group with how much the speeds vary from group to group.

Average - a general term used to describe the CENTRAL TENDENCY of the data i.e., what value describes the "middle" of the data. The most common measure of this is the MEAN, which is often just called the average, and consists of the sum of values divided by the number of values. The mean is usually denoted by drawing a bar over the variable letter e.g. $\overline{x}$ letter e.g--. This is not always the best measure to use. In many cases, the MEDIAN is a better measure. The median is the value which 50% of the data lies above, and 50% lies below, i.e. it is the middle value. The median often makes more intuitive sense, as in economic or speed data.

Bias - bias indicates that the sampling method, analysis procedure used, or other factor, yields results which "unfairly" tend toward certain values or conclusions. For example, common data collection errors--being more careful to record high speed, high occupancy, or larger vehicles--yield biased results. These errors may result in exaggerated average speeds, incorrectly high average occupancies, or invalid vehicle classification counts, respectively. There are many such possible errors, most of which can be eliminated by proper study design and proper random data collection. Other sorts of bias can result from improper application of statistical techniques. For example, if data is simply gathered "shot gun" (i.e. collecting everything that might conceivably be used) style, without prior defining of the hypothesis being tested (i.e. what are we looking for?) then some otherwise valid statistical techniques can not be applied, since they would show differences to be significant which, in fact, were not. If in doubt about a study plan, have it reviewed by trained research personnel.

Categorical Data - categorical data is data regarding variables which belong in one of several categories or classes. For example people may be classified as Democrats, Republicans, Independents or Other. This constitutes categorical data Categorical data commonly results from the use of questionnaires. A special case of categorical data is one in which only two responses are possible e.g. smoker or non-smoker. Coding the results in this case as either zero (smoker) or one (non-smoker) yields a BERNOULLI variable The number of "successes" i.e. 1's in n trials is a BINOMIALLY DISTRIBUTED random variable. In dealing with categorical data, somewhat different statistical techniques, for example binomial distributions and CHI-SQUARED test procedures, may be used.

Chi-square distribution - a nonsymmetrical distribution used in statistical analysis of categorical data, specifically, to test whether the number falling into each category is different from the number that was expected to fall into each category.

Confidence Interval - the range in which some true value is expected to lie, given some CONFIDENCE desired. For example, it may be stated that the average speed of traffic is 59 ± 4 mph at 95% confidence. Thus our sample average was 59 mph and, given the nature of our data, the true value i.e. the true population average will be within 4 mph of this value 95 of the time (when the data looks like ours). Confidence intervals or levels of significance should virtually always be given when reporting information. In addition to averages, confidence intervals can be found for slopes and y-intercepts in regression, variances, probabilities, changes in mean, and ratios of variances. A 95% confidence interval is generally obtained by taking two standard deviations to either side of the sample mean. Thus, if the sample average found were 59 mph and the sample standard deviation were 2 mph, the 95% confidence interval would be 59 mph ± (2)x(2 mph) = 59 ± 4 mph, as above.

Continuous vs. discrete data - Continuous data is data which may be any of an infinite number of values within an interval Speed, for instance, is continuous in that we may give a value as 56 mph, 56.3 mph, 56.32854 mph and so on depending upon the accuracy of our measurement and our needs. Discrete data, by contrast, takes on only a countable number of values, for example the number of crashes in a given year on a segment of highway. Probabilities associated with particular values of discrete or continuous variables must be handled somewhat differently. This is due to the fact that exact values actually occur with discrete variables (e.g. exactly 20 crashes per year) but do not occur with continuous variables (e.g. 20 mph implying exactly 30.000000... will not occur as it is only one of an uncountable infinite set of possibilities).

Control Site - a site at which no treatment takes place. If new signing is installed at an intersection, a control site would be a similar site at which there were no change in signing. The use of control sites allows the researcher to account for extraneous changes unrelated to the treatment. Thus if speeds seem to be slower at the new signing, the control site can help determine whether this is really due to the signing or whether speeds for other unknown reasons are just generally lower. One of the greatest difficulties in using control sites is finding sites which are adequately similar to treatment sites in all respects except the treatment itself. Selected improperly, control sites can lead to bias and unjustified conclusions. Often it is preferable to utilize before/after studies of the same (treatment) site rather than using a control site, since time dependent biases inherent in before/after studies are generally smaller and easier to account for than biases due to control site selection.

Dispersion - the degree to which the data is "spread out." The numbers 20, 41, 10, 6 are more dispersed than 18, 15, 20, 24, even though the average of both sets is the same (19.25). Dispersion is usually given either in terms of VARIANCE, (s^2 for sample data) or of STANDARD DEVIATION (s for sample data). Variance is sometimes simpler to use. In calculations, but for final reporting standard deviation is usually preferred since it is in the same units as the data Standard deviations, s, for the above sets of numbers are 13.55 and 3.27 respectively. Population standard deviation and variance are usually represented by δ and δ^2 respectively.

Distributions - Normal and students t distributions are used in analysis of data to determine confidence intervals, Type I error, probabilities of particular values etc. The t distribution is specifically intended for small samples, but may be used for large samples as well. Since t distribution tables are not as thorough in presenting large sample values, usually the normal (or z) distribution is used for these cases.

Other distributions, for example chi- square or F, are used for certain analysis techniques. Chi-square can be used to assess confidence intervals, Type I errors etc. for sample variances, for example to test the equal variance assumption.

Error - Type I (α) and Type II (β) - A type I error (or α error) consists of mistakenly rejecting the NULL HYPOTHESIS when it is true e.g. saying the average speed of cars from before to after has changed when, in fact, it has not. This type of error is accounted for in giving the significance level of a test i.e. if we say the speed has increased with 95% confidence we imply that there is a 5% chance of our being wrong--or making a type I error. Confidence may be represented as 1 - α.

A type II error (or β error) consists of mistakenly accepting the null hypothesis when, in fact, it is false. This error is made if we say that average speed has not changed, when it actually has. Obviously this sort of error depends upon how large a change we are trying to detect. For example we may "miss" a small 1 mph change without concern since it is not of practical significance, whereas we would like to certainly "find" real changes of 5 mph or greater. In general, if the sample size n does not change, making the β error smaller results in a larger α error 1. The only other alternative is to collect a larger sample. Clearly a reasonable β should be selected so that α does not become unacceptably large or so that inordinate data collection is not required.

Hypothesis - a statement or proposition which is set up to describe a set of facts. Statistical testing is used to determine if the hypothesis should be accepted or rejected. The two types of hypotheses referred to are the NULL HYPOTHESIS *Ho* and the ALTERNATIVE HYPOTHESIS *Ha*. The null hypothesis describes the condition of no change or difference, for example "the speeds did not change with the new signing," or "crashes did not increase this year." The alternative hypothesis simply gives the other possibility, "the speeds did change," or "crashes increased." It is actually the null hypothesis that is tested.

Mean Speed - The mathematical average of all observed speeds.

Median Speed - The 50th percentile speed, or the speed at or below which 85 percent of the observed vehicles are traveling.

Modal Speed - The most frequently observed speed.

Normal - data that is normal is distributed as the normal ("bell shaped") curve and can be analyzed with ordinary statistical techniques. Data should always be checked for normality (visual checks, NORMAL PROBABILITY or RANKIT plots, knowledge about the nature of data, SKEW indices etc may be used).

Pace - The 10 mph speed range containing the greatest percentage of the observed vehicle speeds. The speed limit should be near the upper bound of the pace.

Percent in Pace - The percentage of the observed speeds that were within the 10 mph pace. The higher this percentage is, the more uniform the speeds are.

Percent Speeds - The percentage of the sample vehicles traveling at a speed greater than the indicated speed. Thus, if a speed limit change is being considered, the percentage of violators at various speeds can be determined.

Percentile Speeds - Values of percentile speeds incremented to provide for construction of cumulative speed frequency curves. Each value is the percentage of vehicles at or below the indicated percentile speed. The 50th and 85th percentile speeds are located with the mean and mode speeds.

Population - the set of all measurements of the characteristic in question, e.g. the set of all vehicle speeds past a certain point. A SAMPLE, by contrast, is a subset of the population from which population statistics (mean, Standard deviation etc) are estimated e.g. the set of speeds of every third car past a certain point, or a five minute sample of speeds past a point etc. Often only SAMPLES (rather than entire populations) are gathered and are used to estimate population statistics.

Power - the probability of rejecting the null hypothesis when it is in fact wrong. This is equivalent to 1 - β (see "Error" above).

Range - The spread from the highest to the lowest values observed.

Random - Sampling techniques should be random so that they do not result in bias. Random number tables often can be used to randomize collection, as can careful selection of collection methodology.

Regression - the method of fitting the best line or curve to a set of data points. Often this consists of fitting the best straight line (using root mean squared, RMS, method) to two variable data points. For example the researcher may graph points representing fatalities by vehicle speed, and observe that higher speeds tend to increase fatalities. Regression may be used to fit the best straight line to this data which can then be used to assess how much fatalities increase with each 10 mph speed increase, or to predict fatalities with future speed changes etc. Statistical tests may be performed on the slope and Y intercept of this line, on the value it yields at specified locations, or on predictions made from it. In spite of the ease with which many hand calculators fit regression lines to data, the underlying statistics are relatively complex, conclusions can be totally misleading, and values should be statistically analyzed to yield confidence intervals etc. The facile use of regression has resulted in perhaps more bad information than any other basic statistical procedure.

Sample Size - The number of observations made. Sample size needed for statistical reliability depends on the variability of the population (as reflected by variance or standard deviation) and the level of confidence needed. Sample sizes smaller than n = 30 are generally considered small.

Significance - statistical significance implies that the differences found are likely to be real and not due merely to chance. The significance level for a test represents the weight of evidence for rejecting *Ho*, i.e. the probability of observing a sample outcome more contradictory to *Ho* than the observed outcome. This level of significance is usually called P. Thus if P = 25, there is a 25% chance of having found a more extreme value even if *Ho* were correct. It should be noted then that P is really an α value which has been computed for our particular findings rather than being preset. Confidence may be reported as 1 - α or 1 - P depending upon how results are reported.

Skew Index - A measure of symmetry of the distribution about the mean. A "normal" distribution, symbolized by a bell-shaped curve, would have a skew index between 0.90 and 1.10, and is indicative of randomness of observed values. A positive skewness (> 1.10) is caused by a preponderance of higher values in the sample. A negative skewness (< 0.90) is caused by a preponderance of lower values. The skew index is highly susceptible to minor changes in the distribution. If the value obtained indicates the presence of skewness, consider the possibility that the environment or even the presence of the observer was adversely affecting data.

Skew Index Variance - The variance of the skew index.

Standard Deviation - (Std-Dev), the square root of the variance, another measure of variability used for statistical tests.

Standard Error of the Mean - (STD-ERR), the standard error is the standard deviation divided by the square root of the sample size. The standard error is used to determine the accuracy with which the mean has been determined.

Variance - (VAR), a value calculated based on differences between individual observations and the average of all observations. High values of variance indicate greater variability between observations. The variance is used in statistical computations.

85th Percentile Speed - The speed at or below which 85 percent of the observed vehicles are traveling. This factor is commonly used in establishing speed limits.

5-3.00 VOLUME COUNTS

5-3.01 Types of Traffic Counts

Traffic counts are the most basic type of data collected in the field of traffic engineering. Quite simply, traffic counts involve counting vehicles passing a point for varying intervals of time. They can range from 24 hours per day, 365 days per year, to five minutes of a peak period. Common types of traffic counts, count intervals and the regular traffic counting program of Mn/DOT, are described below. In addition to their use for purely traffic engineering purposes, traffic counts are used to determine vehicle kilometers (**miles**) of travel for the purpose of distributing gas tax revenues throughout various levels of state and local government.

5-3.01.01 Total Volume Counts

The principal use of traffic volume data is the determination of average daily traffic (24 hours) on a particular segment of roadway. The most common product of traffic volume data accumulation is a traffic map identifying the volume of traffic on major roadways. Traffic counts are also used to identify the highest volume of traffic occurring on a segment of roadway during a specific time period, such as the peak period (e.g., 6-9 A.M., 3-6 P.M.), the peak hour, or 5 and 15-minute peaks within the peak period.

5-3.01.02 Directional Counts

Directional counts are counts taken of traffic movements on a roadway by direction of travel. On a segment of highway, directional counts include counts of each movement past the point at which the count is being taken. At an intersection, directional counts are made of each possible movement-through movements by direction of travel, and left and right turns by direction of travel.

5-3.01.03 Lane Counts

Lane counts are directional traffic counts taken for each travel lane on a multilane roadway.

5-3.01.04 Pedestrian Counts

Pedestrian counts are counts of the number of people walking through the area being studied. Pedestrian counts are normally taken only between 8 A.M. and 6 P.M.

5-3.01.05 Metropolitan Freeway Counts

In addition to other counts, each metropolitan area freeway segment is being counted at least once every two years as part of a program monitoring peak period operating conditions. These counts (either 5, 15, or 60-minute increments) are used to determine if congestion is becoming, or has become, a problem; and if so, what corrective measures (such as ramp metering) can be used to alleviate the problem. The Metro District works in cooperation with the Traffic Data and Analysis Section to gather and analyze this data.

5-3.02 Regularly Conducted Counts

The Department conducts five regular traffic counting programs throughout the state. These programs are summarized in Table 5.1 and described below.

5-3.02.01 Automatic Traffic Recorder Program

1. **Location -** Automatic traffic recorders (ATRs) are permanently installed at 125 selected locations throughout the state. These ATR locations were selected to best represent statewide travel and are usually located on trunk highways. Locations on other than trunk highways are determined by population, average daily traffic, and land use. ATR locations in the eight county metropolitan area are based on locale; they include urban, suburban, and outlying areas with road use characteristics that are commuter, mix, and recreational. Combining area classifications with road use classifications - urban commuter, suburban mix, etc., comprise the spectrum of ATR locations in the metropolitan area.
2. **Data Collection -** ATRs are permanently installed and continuously record traffic volumes by direction of travel. All data is accumulated by hour. Approximately one-fourth of the ATRs determine the speed and length of vehicles passing their locations. These are then sorted into one of 12 speed ranges and one of two length categories. Data is retrieved from all locations via voice-grade telephone lines. A central controller polls each location and stores this data by location and date. This data is processed and edited. Monthly reports are prepared showing hourly volumes and appropriate totals and averages. An automatic Traffic Recorder Data Report is published each year showing monthly ADT for the current and previous year for all ATRs. A Traffic Recorder Data Summary is also published annually. This shows days of week, monthly relationships to average daily traffic and to average summer weekday traffic, peak hours of travel, and average hourly traffic. Graphs included show volume variations throughout the year. These reports may be obtained from the Traffic Data and Analysis Section.

PROGRAM	WHERE CONDUCTED	FREQUENCY	NUMBER OF COUNTS MADE
1. ATR Program	Outstate Municipal CSAH Outstate Rural CSAH Outstate Municipal TH Outstate Rural TH 7-County Metro Area	Continuous	125
2. Rural TH	Rural TH Municipal TH	Every other year (even numbers) 48-hour counts	6,000
3. County and Municipal	County and Municipal CSAH CSAH	Over a four year period -- 48-hour counts	27,000
4. Municipal State Aid	State Aid streets within municipalities	State Aid streets within municipalities	4,000
5. Seven-County Metro	Sample of TH and other	Sample of TH and other	9,000

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TABLE OF DEPARTMENT TRAFFIC COUNTING PROGRAMS

TABLE 5.1

5-3.02.02 Portable Traffic Counting Program

1. **Location -** Forty-eight hour machine counts are taken on outstate designated outstate roadways, and on highways in the eight county metropolitan area. Portable traffic counting programs involve placing traffic counters at selected locations to obtain traffic estimates. The sample locations are determined by the Traffic Data and Analysis Section.
2. **Data Collection -** These counts are taken by personnel in the district offices, and are sent back to the Traffic Data and Analysis Section where they are coded by road use. ADT is estimated by applying an appropriate seasonal and weekly adjustment factor. ADT estimates are plotted on work maps where they are compared to historical traffic and land-use data to determine final estimates of average daily traffic. The total number of counts and the time period required to complete the portable traffic counter program are shown in Table 5.1.

5-3.02.03 Computerized Data Collection

1. **Special Counts -** Special Counts are conducted within the metropolitan area on I-35W, I-94, I-494, I-694, and associated ramps. There are approximately 800 permanent vehicle loop detectors currently being monitored by computers at the Traffic Management Center (TMC) in downtown Minneapolis. Volume and occupancy data from these detectors are used to determine operational parameters and evaluate the effectiveness of the traffic management systems on these freeways.

   Data is collected in either 30 second or five minute intervals depending on operational needs. This data is then retained for varying lengths of time. Five minute volume and occupancy counts from detectors are available from computer disk files dating back to January 1, 1994. However, data availability usually lags by one day. Counts may be printed from these files at any interval desired, from five minute to 24 hours. Selected detector data is also available from computer disc files back to 1974. As other newly constructed or reconstructed segments of freeway are added to the metropolitan area network, loop detectors will be installed and added to the number of locations already monitored from the TMC. In addition to detectors installed for traffic management operational needs, detectors are being installed to help reduce the use of portable tube-type counters with their attendant problems and hazards. This should benefit planners and others needing traffic counts from Metropolitan freeway systems.

2. **Tape Processing -** Many portable traffic recorders are designed so that the recorded tape can be read either manually or by translating equipment. These translators convert the coded data into computer format to obtain the desired summaries.

5-3.03 Equipment

5-3.03.01 Traffic Counters

1. **Description -** Manually operated traffic counters are the most commonly used piece of equipment for manual counts, especially for turning movement directional counts. Traffic counter boards are composed of a number of hand-operated counters arranged so that each approach lane to a conventional four-legged intersection is represented by a counter. Usually, a piece of tape is placed in front of each counter row, upon which the observer marks the direction of the movement being counted-through, right turn, left turn, etc.
2. **Operation -** Operation of the counter board is simple. At the start of the count, each of the dials is read and the reading is indicated on a recording form. As each vehicle passes the observer, the counter mechanism is depressed for that particular movement. At prescribed intervals as predetermined by the data requirements - 5-minute, 15-minute, or hourly - the counter is read and the number is recorded. There is no need to set back the counter to zero although most counters are designed to permit this. The actual traffic volumes are determined by subtraction of the initial reading from the final reading.

5-3.03.02 Portable Traffic Recorders

1. **General -** Portable traffic recorders are either accumulative or nonaccumulative. In either case, the machine which is usually used has a rubber hose (or road tube) over which the vehicles to be counted pass. At permanent locations, a fixed loop permanently imbedded into the roadway is utilized to detect vehicles for machine counting.
2. **Accumulative Counters -** An accumulative counter is termed "accumulative" because the counter bank continually advances. Therefore, the counter must be directly read at preselected times. The main parts of an accumulative counter are: (1) the road tube, (2) a dry cell battery to power the unit, (3) a diaphragm, and (4) a counter bank. A surge of air through the tube, caused by a vehicle depressing the tube, deforms the diaphragm and thereby completes an electrical circuit which transmits the electric impulse from the batteries to advance the counter. In most cases, one depression of the road tube advances the counter bank one-half number; two depressions result in one full advancement of the counters or an increase of one number in the counter reading.

3. **Nonaccumulative Counters -** A nonaccumulative counter operates on the same principle as the accumulative counter. However, the nonaccumulative counter records only at specific time intervals - usually 15 minutes - and the recording is made directly upon a paper tape. Only the count for that particular time interval is recorded. Figure 5.1 shows typical portable traffic recorder printed tapes with examples of the recorded data. Both the time and the traffic count are recorded on the tapes. Typical data increments are 15 minutes or one hour. The machines with electronic clocks can be set for intervals as short as one minute.

   a. **Quarter Hour Counts -** The quarter hour record is most widely used because it permits the identification of traffic volumes by quarter-hour intervals, which is useful in the determination of peak-hour volumes. The quarter-hour counter also accumulates the traffic count for the hour clock interval. Both the first 15-minute count and the total counts for that hour can be read directly from the tape. Quarter-hour counts between the beginning and ending of the clock hour must be obtained by subtraction. The count during any quarter-hour period is, thus, the difference between any two counts printed opposite the quarter-hour intervals.

   b. **Hourly Counts -** The hourly count merely totals the count during the hour interval, prints the hourly volume, resets the counter to zero, and advances the hour indicator.

5-3.03.03 P.C. Compatible Counters

1. **Manual -** Used primarily for intersection/turning movement studies, a manually operated 12-button panel can be used in conjunction with a counter that is preprogrammed with the necessary parameters such as date, starting time, site identification, and desired time intervals (generally 15 minute). Form 5.D (Mn/DOT 2944A Rev.) is used in the field with the counting operation so that each movement can be identified with a specific button on the panel. Upon completion of a study the counter can be returned to the office and the count data transferred to a P.C. compatible retriever. Once the retriever is connected to a computer, printouts can be made containing a variety of information such as 15 minute totals for each movement, hourly totals, total intersection volumes, and AM and/or PM peak volumes. An example of these printouts can be seen in Figures 5.2, 5.3A, and 5.3B.

   A second type of manual counter is a microprocessor-based device designed specifically for manual counting. This device has 16 buttons of which 12 are keyed to intersection movements, the remaining four buttons can be used for counting pedestrians, trucks, or buses. Up to 12 hours of count data are automatically stored in the memory in five or 15 minute intervals. Data can be read directly from the counter or transferred to a computer for analysis and printout.

2. **Portable Recorders -** Portable recorders that are P.C. compatible generally consist of two pieces of equipment, a traffic counter and a retriever. The counter is a nonaccumulative portable recorder that is used in the field with associated tubes or loops to obtain volume counts over a prescribed length of time, usually 48 hours. The retriever is used to monitor, set parameters, and collect the stored data from the counter. Prior to beginning a study, the retriever is connected to the counter and various parameters such as time intervals, date, and start time are set. Once the parameters have been set the retriever is disconnected and the counter is left to accumulate the needed data. When the desired study time has elapsed the retriever is returned to the site and reconnected to the counter. The accumulated data is then "dumped" from the counter into the retriever. The retriever is returned to the office, connected to a P.C. and the desired printouts made.

5-3.03.04 Counter Maintenance

1. **ATR Stations -** All of the maintenance of the ATR stations is performed by the Office of Maintenance, Electrical Services Section (ESS). The cost of the power to operate each station is paid for by the District Office that each station is located in. Phone bills are processed by the Business Administration Unit of the Program Management Division.

2. **Portable Traffic Recorders -** The portable traffic counter cases, hoses, chains, and chain locks are maintained and budgeted for by ESS. All counters needing repairs should be transported to the ESS. It is best to spread out the maintenance of counters to avoid delay due to work overloads.

The goal at ESS is to provide repair service when defective counters are turned in. At times, vendors will be used to do some of the repair work. All portable counters are listed in the Office of Maintenance inventory.

Shortly after the first of July each year, each district must advise the Office of Traffic Maintenance of the number of counters required to maintain this counting program. This report goes directly to the ESS and is incorporated into an annual budget request for additional and replacement counters.

5-3.04 Field Data Collection

5-3.04.01 ATR Program

All automatic traffic recorders are in permanent locations. These locations are recorded in the "Minnesota Automatic Traffic Recorder Data Summary" prepared by the Office of Transportation Data, Research and Analysis, in the Program Management Division.

5-3.04.02 Portable Counter Placement

Care should be taken in selecting the location for installing portable traffic-counting equipment. There are two crucial location considerations: (1) placement of the road tube and (2) security of the traffic counter. The selection of an appropriate time and day for counting should also be coordinated with street maintenance and cleaning schedules to avoid road tube damage by maintenance vehicles.

1. **Road Tube Placement -** The road tube should be located along a smooth portion of the roadway to be counted. The hose should not fall along a construction joint as the roadway depression at the joint could cause a misreading of the tube. Care should also be taken to locate the hose far enough away from intersections so that any vehicle crossing the hose would still be moving at right angles to the hose and not turning across the hose. The offsetting of wheels during vehicular traffic turning movements could cause a traffic counter to misread if the counter were located within the turning arc. In securing the roadway tube, PK concrete nails are commonly utilized. The far end of the roadway tube has a clamp through which the PK nail is inserted and driven into a crack in the roadway or, ideally, into the construction joint between the gutter section and the pavement edge. A clamp is also usually attached to the hose at the near side of the counter. This clamp is affixed to the roadway with a nail driven into the construction joint between the gutter section and the pavement edge. Tubes are especially vulnerable to damage by snow plows so they should be checked frequently during inclement weather.
2. **Security -** Traffic counters should be securely chained to a tree, utility pole, or light pole to prevent theft.

5-3.04.03 Other Considerations

Machine numbers should be recorded on the data tape so that corrections can be made if maintenance problems or bad data are encountered. The date, direction of travel, location, and other identifying information should also be included. A length of blank tape should be left on both ends to permit proper machine processing.

5-3.05 Data Recording Forms

This section describes the standard forms utilized for many of the traffic counts described above. Standardized forms are not available for the collection of all data described in this chapter.

5-3.05.01 Data Sheets

Examples of forms used to record data from the portable counters are shown in Form 5.A (Mn/DOT 2914 (5-77)) and Form 5.B (Mn/DOT 29176 (3-77)). Form 5.A is used for recording data from accumulative counters while Form 5.B is used for recording data from nonaccumulative counters.

Accumulative counters must be read directly and the number read should be placed on a form for the appropriate time period. These numbers are then translated to actual volumes by subtraction and the result entered below. Where hourly counters are used, the recording tapes are collected and the traffic volumes are transferred to Form 5.B in the office. Traffic volume data from counters that are P.C. compatible will be produced on computer printouts such as those shown in Figure 5.5A.

5-3.05.02 Directional Counts

Directional, or turning movement counts, are generally taken during AM and/or PM peak periods and are recorded on either a Motor Vehicle Traffic Volume and Turning Movement Field Report or a Traffic Volume and Turning Movement Study or a , Form 5.C and Form 5D (Mn/DOT 2944 Rev) respectively. For examples, see Figures 5.2, 5.3A and 5.3B.

5-3.06 Sample Sizes

Depending on the purpose of the study, sample sizes can vary from a fraction of an hour to 24 hours a day, 365 days a year. Generally, peak periods will be included in all samples. Traffic counts are normally not taken on a holiday nor on the day before or after a holiday. Monday mornings and Friday evenings will generally show high volumes.

Typical sample sizes are:

	Type of Study	Sample Size
1	ADT	24 or 48 hrs.
2.	ATR	24 hrs./day, 365 days/yr.
3.	Signal Warrants	8 to 12 hrs. including both peak periods
4.	Vehicle Classification	16 hrs.

5-3.07 Computations

5-3.07.01 Data Review

The first step in utilizing field data is to check its reasonableness by comparing the data with data obtained from similar locations. If the data is not comparable, the equipment and the field data sheets should be inspected for malfunction or error; and an additional count should be taken for verification.

5-3.07.02 Factoring

The Traffic Data and Analysis Section provides the necessary factors for adjusting weekday machine traffic counts to estimated average daily traffic. These factors are derived from individual counts or groups of counts produced by the automatic traffic recorders. Since all frequencies of data (hourly, daily, weekday, day of week, monthly and ADT) are available at each ATR, the relationships or factors that can be identified and developed are almost unlimited. All factors and factoring procedures are developed and applied by the Traffic Data and Analysis Section.

5-3.07.03 Average Daily Traffic from 48-Hour Portable Counts

Average Daily Traffic estimates can be obtained based upon the portable 48-hour traffic count by applying the appropriate weekday or weekly factor to the count data.

5-3.07.04 Data Summaries

Many types of data and related factors can be developed from the ATR data. Currently these data are summarized in the "Automatic Traffic Recorder Annual Report" available from the Office of Transportation Data and Analysis. The types of data recorded within this report for each ATR station are shown in Figures 5.5A through 5.5E.

5-3.08 Uses of Volume Counts

Volume counts play a major roll in traffic engineering. Their uses include:

1. Determining the need for traffic control devices
2. Obtaining various factors (hourly, daily, weekly, etc.)
3. Developing traffic flow maps
4. Research studies
5. Operational studies
6. Determining ADTs
7. Determining peak periods and peak hours
8. Signal phasing and timing
9. Determining trends
10. Determining the need for channelization
11. Simulation studies
12. Vehicle classifications
13. Calculating crash rates

5-4.00 SPOT SPEED

Spot speeds are the vehicle speeds taken at a specified point along the roadway. The average of such speeds is sometimes referred to as time mean speed.

5-4.01 Equipment

Spot speeds are usually collected by the use of radar or laser equipment, although spot speeds may be gathered during travel time runs by reading the speedometer at specified points along each run. Another method involves the use of a short "speed trap." This trap may consist of a short marked area on the roadway over which vehicles are timed and speeds computed, or may consist of a very short section beginning and ending with vehicle sensors (tubes or electronic) over which an electronic data collection device computes and records vehicular speeds.

5-4.02 Field Data Collection

Regardless of data collection method, the location of collection vehicles, personnel and equipment is of primary importance. The obvious or obstructive presence of these may have a large impact on the speeds of passing vehicles. Because of this, all equipment and personnel should be employed in the most inconspicuous manner possible, and note should be made when reporting information in cases where it is believed vehicular speeds were significantly affected by collection activities. Regarding radar speed collection, the following should also be considered:

1. The angle between the radar and the vehicle path affects speed readings. The further the radar is from a straight roadway section, the slower the speed will read. Although trigonometric adjustment can be made to correct these readings, it is generally more advisable to keep collection in as direct a line with oncoming traffic as possible, which usually means as close to the roadway as possible. Exception to this must be made when the collection vehicle and equipment would tend to affect vehicle speeds significantly.

2. Depending on the use of the data, the observer must consider whether to collect speeds of all vehicles, including platooned vehicles, or only the speeds of unimpeded vehicles. One may collect all speeds, for example, to assess traffic flow during peak periods; whereas only unimpeded vehicle speeds would be collected to assess the impact of speed zone signing.

3. Speed samples may be biased due to larger or faster vehicles being more easily picked up by radar, and vehicles screening vehicles directly behind them. These considerations must be kept in mind both while collecting and while analyzing data.

5-4.03 Data Recording Forms

Typical data recording forms, one filled out and one blank, are shown in Figure 5.6 and blank Form 5.F, respectively.

5-4.04 Sample Size

As a rule of thumb, at least 100 speeds should be collected within the time period under consideration. This will generally provide mean or 85th percentile speeds within ± one mph with 95% confidence. Samples must always be both random and representative. Use a sampling plan which does not distort (bias) values you are looking for. The largest sample size possible is often dictated by the volume at the location and/or the time period being studied. If the volume is very light or the time period very short, large sample sizes may not be possible. In these cases, a minimum sample size of 30 vehicles must be collected. For ordinary conditions this will provide an estimate of mean or 85 percentile speed of ± 2 mph with about 95% confidence. If unusual circumstances prevent even this, the limited data that is gathered should be analyzed by personnel familiar with small sample statistics. It should be noted that the information derived from very small samples may not be adequate for some uses.

5-4.05 Computations

Speed calculations can be done manually, but are usually done with an Excel spreadsheet which is available from OTSO. The basic procedure is to tally the number of vehicles in any one speed category (see Figure 5.6 and Form 5F), accumulatively add the vehicles for each category, and translate the accumulative totals to percentages. A pace (the 10 mph band where most observations occur) is then indicated on the field survey sheet by an arrow. An arrow is also used to indicate the 85th percentile speed.

5-4.06 Uses of Spot Speed Data

Vehicle speed data are used for many purposes including:

1. Establishing speed zones
2. Crash analysis
3. Environmental impacts (noise and air analysis)
4. Designing safety appurtenances
5. Evaluating traffic signal locations
6. Assessing the need for advisory speed limits
7. Setting signal clearance intervals
8. Assessing enforcement needs
9. Assessing speed trends
10. Conducting before/after analysis of various
11. geometric, traffic control, or legal changes

5-5.00 TRAVEL TIME AND DELAY

Travel time studies involve recording the time it takes vehicles to traverse a specified length of roadway. This stretch of roadway may include one or more intersections, or may be a relatively long stretch of freeway. In any case, a long "zone" is often broken into shorter, individually analyzed "links." Travel time data is often reported in terms of delay (travel time in excess of free-flow, unimpeded travel time) or of average speeds in links or zones.

5-5.01 Types of Delay Studies

Delay studies can be broken into two broad categories. The first category is delay caused by traffic flow conditions rather than by traffic control devices. The prime example of this would be delay occurring along a segment of freeway. In this case, most delay is due to slowing in response to congestion, although some stopped delay may also occur. Delay is considered to be excess time spent in the segment above what would be spent if travel were free-flow. The base free flow speed may be determined empirically, using the 50th percentile speed of low volume traffic (<1300 pc ph pl), or may be taken as either the posted limit or some reasonable lower figure. For freeways, use a base equal to 70 for urban and 75 for rural and adjustments for lane width, right shoulder lateral clearance, number of lanes, and interchange density.

The second category of delay studies is that encompassing traffic control devices, particularly traffic signals at intersections. In this case, delay may be considered as excess time over free-flow (green phase, unimpeded) similar to that above, or it may be further refined to establish percent of vehicles delayed, delay per delayed vehicle, delay per all vehicles, and stopped delay per stopped or all vehicles. This refinement of delay is useful in assessing the operation of a traffic control device.

5-5.02 Equipment

The equipment required for delay studies depends upon the type of delay study being conducted. For freeway or other congestion delay type studies at least one vehicle and driver is required. In this case, the driver will need an audio tape recorder with a microphone input so that various checkpoints can be noted during the run. If a second person is used, that person can record the data directly onto a form so that the tape recorder is unnecessary. Intersection travel time/delay studies may be conducted similarly or may be conducted by stationary observers at the intersection. In this case the observers will need forms, clipboards and stopwatches to record the various counts and events.

5-5.03 Field Data Collection

5-5.03.01 Test Vehicle Method

To obtain travel time data, a test vehicle is usually operated within the traffic stream between check points along the route for which travel time information is required. The test vehicle is either operated as a "floating car" or at the "average speed." In the floating-car technique, the driver attempts to estimate the median speed by passing and being passed by an equal number of vehicles. In the average-speed technique, the driver operates the test vehicle at the speed perceived to be the average speed of other vehicles in the traffic stream. Tests have shown that some inaccuracies occur utilizing the floating-car technique, especially during periods of congested flow on multilane highways and on roads with very low traffic volumes. The average-speed technique has generally resulted in more representative test speeds.

The first task in obtaining travel time data is to identify check points along the route where travel time recordings will be entered on the worksheet.

Check points are located at intersections or railroad crossings or other easily-identified physical locations where speed changes are anticipated. Generally, check points in downtown areas should be about two or three blocks apart; in the downtown fringe, four to six blocks apart; and in other areas, eight to 12 blocks apart, depending upon the number of intersecting routes. The check points are indicated on a map and the distances between the check points are either obtained from true distance (TIS) files or from field measurements. Check points should also be referenced by reference post. The data are then transferred to the travel time data recording form.

Travel time test run is usually accomplished by an observer with two stopwatches. The observer starts one stopwatch at the beginning of the run and records the time at each check point along the route. The second stopwatch is utilized to determine the duration of any delays encountered along the route. The locations of delays are indicated on the recording form or noted on a voice recording.

5-5.03.02 Observed Vehicle Method

The observed vehicle method is used only to obtain total travel time information. Observers are stationed at check points where they record the time and the license number of each vehicle which passes an observation point. Later, the license plates are matched using the License Plate Match Computer Program and the total travel time between the check points is determined. Synchronized stopwatches and tape recorders are utilized in this procedure.

5-5.03.03 Moving Vehicle Method

The moving vehicle method presents an interesting way to compute volumes and average travel times in both directions by making only 6 runs (loops) in a test car. The features of interest of this method are:

- It accurately estimates volume by direction for the entire route, in spite of intervening intersections, varying volume etc. This could be done by tubes, but only by setting counters in each section e.g. each block, and then weighting the average by section lengths.
- It estimates average travel time not just of the test vehicle runs, but of all traffic.
- The method applies best to city street type situations.
- Because of the amount of data gathered during each run (total travel time, vehicles overtaken, vehicles which overtake, and opposing direction vehicles met), at least three persons will be required in the test vehicle. Data analysis is straight forward and given by example on Figures 5.10 and 5.11 and Form 5.J.

5-5.03.04 Intersection Study

The most common method of obtaining intersection delay, other than by a running vehicle method as above, is to station observers at the intersection. These observers collect:

1. The total number of vehicles stopped on the approach at regular, specified intervals - usually every 15 seconds unless the pre-timed cycle length is an even multiple of 15 seconds, in which case 13 seconds is used.
2. The total number of vehicles stopping and the total number not stopping.

In addition, other data is often collected during the delay study, such as movement counts, road and lane numbers and widths, and phase lengths. These are not required to compute delay, but are useful in assessing intersection performance.

5-5.04 Data Recording Forms

Several forms, both completed and blank, are shown in Figures 5.7 through 5.12 and Forms 5.F through 5.K, respectively. Note that the forms are self explanatory, and include notes regarding their use.

Travel time forms shown include provision for recording spot speeds (speedometer readings). Intersection delay forms include a worksheet area for computations.

5-5.05 Sample Size

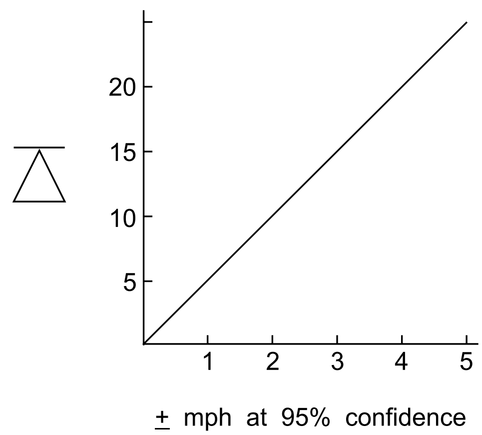
1. **Test vehicle method**: at least 6 runs.

   This will provide a range for the computed mean speed shown on the graph below, where Δ is merely the average difference in speed from one run to the next for the six runs:

$$\bar{\Delta} = \frac{[S_1\text{-}S_2] + [S_2\text{-}S_3] + [S_3\text{-}S_4] + [S_4\text{-}S_5] + [S_5\text{-}S_6]}{5}$$

$$\bar{\Delta} = \sum_{i=1}^{5} \frac{[S_i\text{-}S_{i+1}]}{5}$$ where S_1 = speed for the 1st run, etc.

The graph is as follows:



Example: If the average difference in run speeds, is 15 mph, and the overall average speed has been computed as 41 mph, then (from the graph) the speed may be reported with an estimated precision of 41 mph ± 4 mph with 95% confidence.

2. **Observed Vehicle Method**: at least 30 matches. If only 6 matches were made, accuracy could be estimated as above. Since these are usually easier to collect in a short period of time than are actual travel time runs, it is wiser to collect a minimum of 30 samples to avoid small sample problems and to increase precision. A minimum of 30 samples will generally provide a precision of ± 2 mph with 95% confidence.

3. **Intersection Study**: Peak period or peak hour - gather data for 1 entire period.

   Notes: Samples should be gathered on typical days. In general, Monday AM and Friday PM peaks should be avoided. Days with inclement weather or on which significant crashes, stalls etc. occur should be avoided. If these occur during a study, the study must be partially or completely redone.

5-5.06 Computations

Computations are as outlined above, or as indicated on the data collection forms.

5-5.07 Uses of Travel Time/Delay Studies

This data has many uses, including:

1. Evaluation of level of service
2. Selection of traffic control devices
3. Before/after studies
4. Design of traffic control devices
5. Signal timing selection
6. Calculation of user costs
7. Identification of trends
8. Identification of sections needing geometric revision

5-6.00 VEHICLE OCCUPANCY

Vehicle occupancy refers to the number of persons in each vehicle, including the driver, and often excludes both buses and commercial trucks. This data is distinct from lane occupancy, described in section 5-106.00.

5-6.01 Equipment

The equipment required for data collection consists of pencil and paper, a watch, and a manual counter of at least six "banks." Usually a vehicle is needed to get to the site and to sit in during data collection. At very low volume sites, data can be collected using tally marks rather than counters, although even where volume is low counters are more convenient.

5-6.02 Field Data Collection

Data is collected manually by field observers with six bank counters. One "bank" (individual counter) is used for each of:

1. Vehicles with driver only
2. Vehicles with 2 persons
3. Vehicles with 3 persons
4. Vehicles with 4 persons
5. Trucks
6. Buses

The occupancy data collection form has columns for 5, 6 and 7 or more persons per vehicle as well. Since the number of vehicles with occupancies this high is usually small, these are collected by simple hand tally marks near these columns on the form. Cumulative totals are recorded on the form at 15 minute intervals for all data (counters are NOT rolled back to zero).

5-6.03 Data Recording Form

Completed and blank data recording forms are shown in Figures 5.13 and Form 5.L, respectively.

5-6.04 Sample Size

For most locations data may be collected for one session during the time period under consideration e.g. peak hour. To find the differences shown in the table below with 95% confidence, the minimum sample size should be as follows:

to detect a difference in occupancy as small as	collect a sample size of
.01	19,208
.02	4,802
.03	2,134
.04	1,201
.05	768
.06	534
.07	392
.08	300
.09	237
.10	192

5-6.05 Computations

Computations are generally self-explanatory. The "bottom line" information usually includes the average number of persons per car, e.g. 1.21 persons/car, given to hundredths. Also often presented are percentages of persons in vehicles with one occupant, two occupants, three occupants etc. Note that this is different from the percentage of vehicles carrying one occupant, two occupants etc. Since occupancies tend to vary with time of day, the time period during which the study was conducted is also given.

5-6.06 Use of Vehicle Occupancies

Occupancy data are usually used to assess the impact of various geometric (e.g. the addition of a high occupancy vehicle, HOV, lane), control (e.g. the implementation of metering), or operational (e.g. the use of additional bus runs) changes. Occupancy data also reveals the total number of persons utilizing a facility, or a theoretical maximum people carrying capacity. Trends in vehicle occupancy are often caused by new HOV facilities, rideshare promotion, changes in gasoline prices, and changes in bus service.

5-7.00 LANE OCCUPANCY

Lane occupancy is the percentage of time a point on a lane is occupied (covered) by a vehicle. This is directly related to the density of traffic flow, and thus also to speed, level of service (LOS) etc.

5-7.01 Equipment

Occupancy data are usually collected using six by six sawn in loop detectors. Although these are not strictly point sampling devices, the percentage of time such a detector is occupied yields an adequate occupancy value. Occupancies could be obtained less directly from speeds, headways, densities, aerial photography etc. but this is rarely, if ever done.

5-7.02 Field Data Collection

Data collection is usually done by automated equipment. Field collection of volumes and speeds may be used to estimate occupancies, but is not generally done.

5-7.03 Data Recording Forms

Data is usually recorded by automated, computer equipment.

5-7.04 Sample Size

Occupancies are collected for the time period of interest (usually in 30 second, one minute or five minute intervals) and used or reported. Since they are usually used only in evaluating flow during that same period, the sample size of one is the entire population, and any error is a result of equipment error etc. rather than sample size considerations.

5-7.05 Computations

A relationship between density and occupancy is approximated by:

Density = 2.5 veh/lane mile x % occupancy

where occupancy is given in percent and density in vehicles/lane mile.

5-7.06 Uses of Lane Occupancies

Occupancies are used primarily to assess traffic flow during real time traffic management. This data is used as input into computer algorithms which control changeable message signing, metering rates, and traffic flow information devices.

Occupancies are also used to evaluate whether flow is at capacity, to assess changes in flow conditions, and to evaluate the impact of crashes or stalls on traffic flow.

5-8.0 VEHICLE DENSITY

Vehicle density, mentioned above as being indirectly obtainable from lane occupancy information, is occasionally obtained directly. Information is usually presented in units of vehicles per mile (kilometer) or vehicles per lane mile (kilometer) [(VPLM) or (VPLkm)]. According to the 2000 “Highway Capacity Manual”, density is the primary measure use to calculate the Level of Service for basic freeway segments. The Level of Service thresholds are summarized below:

LEVEL OF SERVICE	DENSITY RANGE (pc/mi/ln)
A	0 - 11
B	11 - 18
C	18 - 26
D	26 - 35
E	35 - 45
F	>45

5-8.01 Equipment

Density may be estimated from lane occupancy data, using the same collection equipment (5-6.01). Other methods of estimating the number of vehicles on a section include aerial photography, which requires the use of an airplane or helicopter as well as appropriate photographic equipment. Although this is a direct, accurate method of determining instantaneous vehicle density, it is also complex, costly and in most cases of more theoretical than practical interest.

5-8.02 Field Data Collection

See section 5-7.02

5-8.03 Data Recording Forms

No special forms are required. If density is estimated by counting volume into and out of a section of known initial state (i.e. the number of vehicles on the section at the start of the study is known or assumed), then volume counting forms may be used.

5-8.04 Sample Size

Usually the density is averaged for the time period in question, similar to occupancy data. Due to seasonal variation, trends, variation in the time of occurrence of peak density etc. precise long term densities are not normally given, or if given, are presented without confidence intervals. If densities are used for before/after studies (this is rare), sample sizes may be established based on appropriate variances.

5-8.05 Computations

See Section 5-7.05

5-8.06 Uses of Vehicle Densities

Vehicle densities are used to assess the quality of flow on a roadway section and are the primary measure of Level of Service for freeway segments. Most uses are theoretical rather than practical.

5-9.00 QUEUE STUDIES

5-9.01 Types of Queue Studies

Queue studies are of two primary types, related to two general ways of defining a queue:

1. A line of stopped (or nearly stopped) vehicles created by some traffic control device, notably a signal or a stop sign, or due to some movement restriction, for example a queue buildup behind a vehicle waiting for a gap in order to make a left turn.
2. A number of cars moving as a group or definable platoon moving at a speed less than free flow speed due to congestion or some particular traffic stream and/or roadway anomaly (e.g. congestion induced shock waves, queues formed upstream of bumps, potholes, lane drops, stalled vehicles etc.).

This section is concerned only with the first type of queue, which may be simply called a waiting line of stopped vehicles. The second type of queue is used far less frequently and will not be considered. For a discussion of this second type, see references.

5-9.02 Equipment

Collection equipment for queues usually includes a stopwatch and a clipboard with appropriate forms. Special equipment such as delay meters, intersection counting boards or programmed hand held computers may be used, especially when delay, capacity or other characteristics are the end products desired rather than queue lengths themselves. In this case the use of electronic equipment may significantly reduce data reduction person-hours.

5-9.03 Field Data Collection

Data is usually collected by stationing an observer within view of the queue, and having this observer record queue lengths at set intervals, see Form 5.M. For intersection studies, an interval of 15 seconds is usually used, as long as the cycle is not an even multiple of this, in which case another interval, usually 13 seconds, would be used. Other studies often use 30 second intervals, which allows more accurate counting of long queues. For this reason, a longer interval may also be used for intersection studies if the queue is difficult to count at shorter intervals. Another method of counting very long queues is to count the number of vehicles back to a known point, and then count only the remainder or "tail" at each interval thereafter when vehicles are backed up beyond the known point. Later the length of the tail and the vehicles back to the known point are summed to find the actual queue length. This system is particularly useful where the queue is constant, such as at ramp meters.

5-9.04 Data Recording Forms

For delay studies at intersections, the forms presented in section 5-5.04 are used to record queue lengths. A more general queue length form is given in Figure 5.12. If all that is needed is maximum queue length, which is sometimes the case, no specialized form is needed.

5-9.05 Sample Size

For delay at intersection studies, see section 5-5.05. Other queue studies usually require collecting queues at 30 second intervals over the time period in question on three separate occasions. The primary reason for collecting data three times is to ensure that data has not been collected on an anomalous day. If it is certain that a day is "typical," queues may be collected only once.

5-9.06 Computations

Maximum queue length (Maximum queue): This is taken directly from data recording forms.

Average queue length: This is the mean of all measured queues (Sum of all lengths ÷ number of queues counted).

Median queue: From a driver's standpoint, this is more meaningful than the mean. The median queue is the queue with 50% of queues longer than it. Easily obtained by writing queue lengths in order by length then by observation. If the number of queue lengths is odd, take the middle length; if the number of queue lengths is even, take average of middle two lengths. Also called 50th percentile queue.

Queue delay: See section 5-5.03.04

Note that all of the above report queue lengths in terms of numbers of vehicles. For some special purposes queue lengths may be reported in terms of meters or delay, although these are usually derived rather than directly collected.

5-9.07 Uses of Queue Data

In addition to use in delay studies assessing the performance of traffic signals, ramp meters or other traffic control devices, queues may be used directly to quickly evaluate timing plans, the quality of traffic flow, or the need for additional facilities and appurtenances.

5-10.00 VEHICLE CLASSIFICATION

Vehicle classification consists, in its most basic form, of determining the percentages of automobiles and trucks in the traffic stream at a particular location. Often an additional category of buses is used. Further, the category of trucks is sometimes subdivided into semi and unibody styles, or into subdivisions based on length or number of axles. Other categories sometimes considered separately include motorcycles, vans and pickups, taxis, and recreational vehicles (RVs). What categories are utilized depends upon the purpose of the study, the level of the category in the traffic stream, and the categories used in previous studies which will be used for comparison. Also, some categories are avoided due to the difficulty of collecting the data. Trucks by length in meters is an example of this, as are categories based on vehicle ownership.

5-10.01 Regularly Conducted Counts

Vehicle classification counts are conducted at numerous stations throughout the State by the Transportation Data Research and Analysis Section. Information regarding the classification categories used and sites available may be obtained from that office.

5-10.02 Equipment Used

Most special purpose classification counts are done manually with no more than a multiple bank mechanical counter and a data recording form. Occasionally the data is first recorded on film or video tape and then the data is extracted. This may allow filming during unusual hours or for long periods while confining data extraction to normal working hours. Also, simple data may be gathered from tapes or film played back at fast speed, reducing actual collection time. Some portable electronic equipment is also available to do classification counts, usually based on axle spacings. This equipment can greatly simplify collecting large samples, but may restrict the classification categories that may be used, e.g. the equipment will not distinguish between buses, RVs, and trucks, between private and commercial vehicles etc.

5-10.03 Field Data Collection

Simple classification data is sometimes a by-product of other studies. For instance, collection of vehicle occupancies generally includes a separate tally of trucks and buses (5-6.03). Field collection is usually done with tally marks on a form (5-10.04) or with counters sufficient to accumulate each of the classification categories desired.

One of the common difficulties involved with field data collection is defining categories clearly enough so that the field data collector can count each category confidently. Typical problems with categories include: In what category is a motorcycle, taxi, airport limousine or vanpool? Is a delivery van, a van or a truck? Are pickups with crew cabs and six tires pickups or trucks? What about recreational vehicles or cars pulling boats, trailers or campers? What is a semi cab without a trailer?

If the study has separate categories for each of these vehicles, the problem disappears. This is usually not the case. There may be only two to five categories, so that study planners must decide how to handle questionable cases. Occupancy studies done by the TMC often involve only three categories: automobiles, trucks, and buses. In this case motorcycles are classified as cars, taxis and limousines as buses, van pools as cars, delivery vans, six wheel pickups, RV's and cars towing trailers or boats as trucks etc.

The way the categories are defined depends upon which categories are used and the purpose of the study. Must the study differentiate between commercial and private vans? Is motorcycle usage being studied? Once the purpose of the study is clearly defined, the categories must be selected and defined so that appropriate data is collected. Both the study purpose and the definitions must be passed on to the field data collectors to allow them to make quick, appropriate real-time decisions. After the first session of data collection, field notes and comments should be reviewed to allow "fine tuning" of the categories and definitions.

5-10.04 Data Collection Forms

Typical forms are included as Figures 5.13 and Form 5.N. Note that often special purpose studies will require the creation of new forms for data collection.

5-10.05 Sample Size

In most cases extreme accuracy is not needed for classification studies. The usual procedure is to collect classification data for one session during the time period of interest e.g. peak hour.

5-10.06 Computations

Usually computations consist of simply figuring the percent of each category of vehicle for the time period studied. In low volume situations, the classification count may include all vehicles, in which case the number of vehicles in each category is also immediately available. In other cases, the percentages obtained may be applied to separately collected volumes in order to estimate the number of vehicles in each category.

5-10.07 Uses of Vehicle Classifications

Vehicle classifications are used in capacity computations, in assessing the impact of traffic regulations or controls not directed at all types of vehicles, in some economic analysis of travel or delay, and to evaluate the people moving effectiveness of HOV and other facilities.

5-11.00 LICENSE PLATE CHECKS

5-11.01 Equipment

In all but the lowest volume situations, it is simplest to read license numbers into a cassette recorder. Microphones with integral on/off switches are easiest to use and conserve tape. In the office the data is recorded onto a computer coding form. If the license numbers are being used for simple matching, as in an origin destination (O-D) study, the data can be evaluated by hand, by PC using an ad hoc program, or by programs available at IMB (License plate matching system, DTTC 6110 and DTTC 6210).

If the license plates are being recorded for the sake of obtaining address labels, as for mail-out questionnaires, the numbers, recorded on general purpose coding forms should be sent to the Department of Public Safety for processing.

5-11.02 Field Data Collection

The observer should be stationed as near the roadway as possible, at a point where the traffic is slow or stopping. Because of dirt and salt, the winter months are usually bad for collecting plate numbers, although an adequate sample may be taken. The observer should face oncoming traffic to read plates. Plate numbers are read into the cassette recorder. When an O-D Study is being conducted, begin and end data collection times for various observers must be coordinated to account for the distance between observers, the traffic already in the system, and the desired time interval.

5-11.03 Data Recording Forms

No special forms are necessary.

5-11.04 Sample Size

Usually as close to a 100% sample as possible is gathered during the time period in question. This is especially important for O-D studies. For questionnaire use, sample size may be dictated by the relevant time period or may be arbitrarily limited to a minimum of about 250. Expect a return rate of about 25% on mail back questionnaires.

5-11.05 Computations

For O-D studies, information computed usually includes the percent of traffic entering at a specified location and exiting at one or more downstream locations.

Questionnaires usually require computing the percent of respondents giving each specified answer, the percent of respondents by category (e.g. heavy or light users of a facility) giving each specified answer, and a compilation of written remarks (See references).

5-11.06 Uses of License Plate Checks

License plate data is used for:

- Obtaining addresses for use in mailed questionnaire data acquisition.
- Obtaining vehicle fleet information (average age, size etc. of vehicles).
- Traffic pattern ("O-D" or in/out) studies.

5-12.00 WRONG WAY MOVEMENTS

5-12.01 Equipment

A wrong way movement counter is available at the TMC. This counter provides both a count of wrong way vehicles and a picture of each wrong way vehicle. Equipment that merely counts is not adequate in many locations e.g. at the top of ramps or at intersections on grade, since rollbacks incorrectly count as wrong way.

5-12.02 Field Data Collection

TMC Research personnel will instruct users on proper installation and use of equipment. Short term studies in the metro area may be conducted by TMC staff, upon request.

5-12.03 Data Recording Forms

No special forms are required.

5-12.04 Sample Size

The counter is usually left at the site for one week.

5-12.05 Computations

The only computations usually performed are wrong way movements by time period (hour, day, year etc.) and the ratio between wrong way counts and volume:

$$\frac{\text{\# of wrong way movements}}{\text{total volume}}$$

5-12.06 Uses of Wrong Way Information

Wrong way information is used to assess the need for, or impact of signing, marking and geometric conditions or changes.

5-13.00 CONFLICT ANALYSIS

In many cases traffic problems are very hard to assess by crash studies since:

1. Sufficient time must pass to accumulate a meaningful crash history.
2. Many conditions show up only weakly or not at all in crash statistics in spite of having a significant impact on traffic flow.

Often, the best way to assess these problems is by using conflict analysis techniques. These techniques involve observing traffic and noting instances of apparent conflict, such as lane changing, brake application, or other erratic driving practices.

5-13.01 Equipment

Usually manual tally sheets or count boards. For some studies video tape or film equipment is preferred for data collection.

5-13.02 Field Data Collection

Field data collection consists of collecting:

1. Volume information
2. Counts of conflicts by type of conflict.

Depending on site characteristics, one or more of the following conflict categories is used:

- Left turn, same direction
- Right turn, same direction
- Slow vehicle, same direction
- Opposing, left turn
- Right turn, cross traffic from right
- Left turn, cross traffic from right
- Through, cross traffic from right
- Left turn, cross traffic from left
- Through, cross traffic from left
- Others

These are all purely conflict, multiple vehicle categories. When a conflict occurs, it is recorded by category. If this conflict produces a secondary conflict e.g. one car has to brake for a left turning vehicle, which causes a second vehicle to brake for the braking vehicle, then a secondary conflict is recorded by primary conflict category (or sometimes by secondary conflict category). Further conflicts resulting from the primary conflict are not recorded.

In addition to actual conflicts, conflict studies often include data that may be considered erratic maneuvers:

- Backing up
- Driving Slowly
- Exiting from wrong lane
- Sudden lane changing
- Run off Road
- Stopping
- Braking or encroachments:
- Center line
- Edge line
- Stop line
- Shoulder

All of these are single vehicle measures.

5-13.03 Data Recording Forms

Forms should be produced for the specific study to be performed. Data to be logged must include the number of each category of conflict used, and the total volume of traffic exposed to the potential conflict.

5-13.04 Sample Size

As long as it is certain that the day of study is not anomalous, one data collection effort during the time period in question should be sufficient.

5-13.05 Computations

Computations include conflicts per total volume and conflicts per time period. To determine the significance of changes in conflicts from before to after, the following may be used:

$$Z = \frac{P_1 - P_2}{\left(\frac{N_1P_1 + N_2P_2}{N_1 + N_2}\right)\left(1 - \frac{N_1P_1 + N_2P_2}{N_1 + N_2}\right)\left(\frac{N_1 + N_2}{N_1\,N_2}\right)}$$

Where: P_1 = before % of conflicts

i.e. $\frac{\text{no. of conflicts}}{\text{total potential conflicting vol.}}$

P_2 = after % of conflicts

N_1 = total potential conflicting volume before

N_2 = total potential conflicting volume after

This Z value can be used with standard tables to determine whether the null hypothesis, that is whether the true population proportions before to after are identical, should be rejected, and at what level of significance.

5-13.06 Uses of Conflict Information

Conflict information is used to estimate crash potential at a location or to evaluate the impact of various operational changes. Many researchers feel conflict analysis allows assessment of safety without actually waiting for a long term historical record of crashes to occur. In addition, safety or impact of short term measures may be studied, even though no crashes may occur during the abbreviated implementation period.

5-14.00 QUESTIONNAIRES AND SURVEYS

Questionnaires are often used to obtain driver or agency attitudes, knowledge and use regarding various traffic control or informational measures. Surveys usually involve either in person interviews, phone interviews, handed out/mailed back questionnaires, or mailed out/mailed back questionnaires. Sometimes these methods are combined, for example those not returning a questionnaire will be contacted and interviewed by phone.

5-14.01 Equipment

No special equipment is ordinarily required. If addresses are derived from license plate numbers, See section 5-11.01.

5-14.02 Field Data Collection

"Field" data collection consists of either in-person or phone interviews, or collecting license plate numbers (5-10.0). Interviews should be conducted in an organized manner using a set format (group of questions).

5-14.03 Data Recording Forms

Data recording forms consist of either survey forms filled out by an interviewer or of questionnaires. Questionnaires are virtually always study specific, and a variety of mail-back formats are available. The questions used must be very carefully thought out. Even with careful preparation, it often happens that when questionnaire data is actually evaluated it is discovered that key points were not addressed, or if addressed were not clarified and corroborated with related questions. Preparation of questions should be pursued only after it has become absolutely clear what the objectives of the study are. The "shotgun" (i.e. collect everything anyone can think of) method of questionnaire design does more harm than good, and the results often multiply the confusion rather than provide the answers.

Unnecessary questions should not be asked and all necessary questions must be included. Questions must be asked in a logically neutral (to avoid biasing answers) and an emotionally inoffensive (to avoid antagonizing the respondent) way. Some rules of thumb for questionnaire development:

1. Always use an introductory paragraph or page which states the subject of the questionnaire, the purpose of the questionnaire, and the name of the agency and/or section conducting the study.
2. Never ask personal questions such as age, sex or income unless they are clearly required for the study.
3. Order the questions in a logical way. Funnel or filter questions should allow the respondent to skip irrelevant questions.
4. Before using a questionnaire, have it reviewed and completed by various people (pilot test) to ensure that questions are asking what you think they are asking, and to detect ambiguities. Questionnaire development is not a one person job.
5. Response rate is a very important factor in evaluating questionnaire information. Unnecessarily long (one page or less is preferable) or poorly written questionnaires reduce response rate. A response rate of 40-60 percent may be expected for a single mailing, mail out, mail back form.
6. Phrase questions in such a way that the answer is not biased. Some questions bias the answer by leading, embarrassing, complementing etc. the respondent.
7. Word choice is critical. Words should be simple, unambiguous, and emotionally neutral.
8. There is a tremendous variety of question types (dichotomous, multiple choice, rating, ranking, open-ended etc.) and evaluation procedures. If you are not clear on what to use or how to use it,ask someone who experience with designing questionaires.

5-14.04 Sample Size

The sample size required for statistical evaluation of responses depends on return rate and the specific question. Generally, at least 100 questionnaires should be distributed. This ensures a returned questionnaire number of at least 30, and avoids certain small sample considerations. When feasible, 300 or more questionnaires should be utilized to strengthen results. In depth small sample surveys, multiple mailings, and phone follow-up are sometimes used but generally require more time consuming collection, more experienced data collection personnel, and more expertise in evaluation.

5-14.05 Computations

Computations always include the percent of polled persons responding, and the percent of all respondents giving each possible question answer. Often various subsets of responses are picked out for evaluation, e.g. the percent of all commuters making various responses. Statistical techniques are not always applied and when they are, they depend upon the nature of the specific question. See references for a more thorough discussion of statistical evaluation of survey responses.

5-14.06 Uses of Questionnaires

Questionnaires and surveys are used for O-D studies, to determine driver attitudes regarding traffic control devices, to clarify the meaning of other data, such as travel times or occupancies, to verify driver understanding of signs, control devices etc., and to determine driver concerns.

5-15.00 OTHER STUDIES

Various other studies are occasionally performed by traffic personnel. Many of these are used in conjunction with the studies already covered.

5-15.01 O-D Studies

Full blown O-D studies are virtually never conducted by traffic engineering personnel. Smaller, limited O-D studies are sometimes performed to evaluate a certain length of roadway or a limited number of entrances, exits or intersections. These are not true O-D studies in that the actual origins and destinations of the vehicles are not known, only where they entered and exited a particular road. The usual method of collecting this data is by using a license match methodology (5-11.0).

Another sort of small O-D study is conducted to determine the origins and destinations of vehicles crossing a certain point, or using a certain facility (e.g. an entrance ramp). The usual method for conducting this is to collect license numbers (5-11.0) and mail questionnaires to users (5-14.0).

5-15.02 Compliance (violation) Studies

Compliance with various traffic control devices is often studied. In general, such a study consists of counting the number of cars complying and the number violating. The ratio of violators to compliers or the percent of violators is then judged for acceptability, or compared between control and treatment sites or from before conditions to after. Statistical evaluation of changes in percent violating may be conducted using the formula given in Section 5-13.05.

5-15.03 Mass Transit Studies

Some metropolitan area studies, for example studies of HOV facilities, involve monitoring bus loadings. Bus loading and route information may be obtained from the Metro Transit.

5-15.04 Wheel Path Studies

Some evaluations, notably studies of roadway markings, involve describing the paths of vehicles (lane placement) under varying conditions.

Equipment used may include a series of road tubes ending at different points within the lane, video tape or film cameras, specialized lane placement counters, or simple counters used with field observers.

5-16.00 STUDY METHODS AND EQUIPMENT

5-16.01 Data Collection

5-16.01.01 Sample Data

Most data collected for traffic engineering studies is sample data. Sample data by definition are a subset of the universal set, and may or may not be an accurate representation of the universe. Whether or not an observation is a sample or just part of a sample depends on the eventual use of the data. For example, in a vehicle classification count identifying autos, trucks, and buses, each vehicle observed would be a sample. If that same data were totaled and considered a volume count for the duration of the time the count was conducted, it would be a volume count of sample size one.

5-16.01.02 Sampling Error

When the sample size is very small compared to the population, the probability that the sample will be a good representation of the population is low. The term "sampling error" refers to errors incurred when estimates based on sample data are used to make some judgment about the population parameters. Sampling error is normally high with small sample sizes and decreases as the sample size increases. Sampling error is controlled in the design of the study. Sampling error should not be confused with sampling bias or mistakes in gathering and analyzing data. Sampling bias refers to an error in study design that prevents each item or member of the population being studied from having an equal chance of being selected or sampled.

5-16.01.03 Sample Size

The types of data collected and the methods used to collect data for research purposes are generally the same as for operational studies except that the quantity and detail is greater in research studies. Exceptions may occur when sample size requirements dictate special data acquisition techniques or devices.

The larger sample sizes required for research purposes are due to the variability of traffic parameters. Because parameters vary naturally, small observed differences can be mistaken for differences resulting from controlled changes. Thus, true differences may be obscured and incorrect conclusions may be drawn by using small samples. Statistical methods can be used to determine required sample sizes. If questions arise relating to how many samples are needed or what typical values should be used, the research staff can be asked for help.

5-16.01.04 Study Design

A good study design must take into account the final objectives of the study, the level of accuracy required, the manpower and equipment available, and the cost. The research staff can help determine study methods, types of data to collect, when to collect data, etc.

5-16.02 Data Processing

Most of the data collected for research studies can be processed by computers. If a large amount of data is to be collected, it may be expedient to design survey forms for easy keypunching or entry at a terminal. In addition, various pieces of equipment have been developed which allow collected data to be dumped directly into an IBM PC or compatible. This greatly reduces processing time although it requires a trained processing person to conduct the computer operations. Several software packages are available to do actual analysis, although the mistake is often committed of conducting certain types of data breakdown and analysis simply because it is available in the software, rather than because it is appropriate. Worthwhile analysis is thus often missed, and faulty conclusions drawn from the computer generated information.

5-16.03 Statistical Analysis

Statistical reliability is an extremely important consideration in research because collected data--for example, measures of speed and volume are only estimates of the true value. For instance, in a speed study the average speed is calculated from the values of the speed of individual vehicles sampled at a given site at a particular point in time. This average is assumed to represent the average speed of all vehicles on all days at all times. Stated another way, the mean or average obtained by sampling is assumed to be the true average for the entire population. The validity of this assumption depends on the quality and variability of the individual observations. If the variability is low and/or the sample size is high, we can be relatively confident that we are close to the true value. The variability parameter, known as the standard deviation(s); or its square, the variance (s^2), can be used to measure these fluctuations "Statistics" or "statistical analysis" is the computation and use of variability parameters.

5-16.03.01 Average Value

One important application of statistics in traffic research is an analysis of the accuracy of the estimated average value.

The variance formula which is used is:

$$S^2 = \frac{\sum (X_i - \overline{X})^2}{n - 1}$$

or the summation of the differences between individual observations and the average value, each difference having been squared (or multiplied by itself), and the total divided by the number of observations minus one. Several versions of this formula may be found (in standard statistics books) that make the computation for grouped data or other special applications much easier.

The value of the population mean can be estimated as being within the range of X ± "t" (sε) or the sample average plus or minus a confidence factor ("t") times a parameter known as the standard error of the mean, where sε $s/\sqrt{n}$ and t is a table value. The most typical value of "t" is 1.96 which corresponds to a 95 percent confidence level (95 chances out of 100 that the decision is correct) when the sample size is large.

For example:

If X = 50 mph and s = 10 mph, and n = 200, we can say that at the 95 percent confidence level the true population average speed, U, is between X ± 1.96 ($10/\sqrt{200}$) or between 50 mph ± 1.4 mph (48.6 to 51.4 mph). To illustrate the effect of sample size, for the same level of confidence but n = 10, U = 50 ± 1.96 ($10/\sqrt{10}$) = 50 ± 6.2 mph (44 to 56 mph). Thus, the smaller the sample size, the wider the range must be to have the same probability that the true mean is included.

5-16.03.02 Volume Variability

Another example of statistical analysis can be used to show a typical volume variability problem. For instance: If: X = 2,000 vehicles per hour (VPH), s = 80 vph, and n = 3 days of sampling, the true average volume for that time at that location is 2,000 + 3.18 ($80/\sqrt{3}$) or 2,000 ± 147 (1,853 to 2,147 vph) a range of ± 7.4 percent! (3.18 = "t" value for n=3) This possible error must be acknowledged when drawing inferences for research purposes.

5-16.03.03 "Before-After" Comparisons

Another example of statistical methods is the comparison of two different situations, for example, the average speed before and after new lanes are opened. In a typical case, it may be difficult to determine if an observed difference was due to variation within the population or due to a roadway change. The difference can be tested statistically by what is known as the "t" test: For example:

If $x_1 = 50.0$ and $s_1 = 10$ mph and $n_1 = 100$ v
$x_2 = 53.0$ and $s_2 = 10$ mph and $n_2 = 100$

The calculated "t" value = $\frac{x_2 - x_1}{s_d}$

where $s_d = s_p\sqrt{\frac{n_1 + n_2}{n_1 \times n_2}}$

and $s_p^2 = \sqrt{\frac{s_1^2\,(n_1 - 1) + s_2^2\,(n_2 - 1)}{(n_1 - 1) + (n_2 - 1)}}$ = 10 = pooled variance

$$s_d = (10)\left(\sqrt{\frac{100 + 100}{10{,}000}}\right)$$

$$10 \times 0.1414 = 1.414$$

and $t_c = \frac{53.0 - 50.0}{1.414} = 2.12$

From statistical tables it can be determined that, at a 95 percent confidence level, a value of 1.65 would be outside limits of chance and, since a greater value was calculated, that the differences are real and not due to chance. If the sample size were 200 instead of 100, the calculated "t" value would have been 3.0 and the difference would have been even more meaningful. At n=200, a difference of only 3.2 km per hour (**2.0 miles per hour**) would have been statistically significant. If more than two conditions are being compared such as 1970, 1971, 1972, and 1973 average speeds, the "t" test is not appropriate. An analysis of variance test as described in statistical text books will determine if any statistical significance differences are present.

5-16.04 Special Equipment

5-16.04.01 Time Lapse Movie Camera--16MM

Complicated traffic situations or other difficult conditions can be filmed and then observed repeatedly either in real-time or on a frame-by-frame basis. In this way, various measures of driver performance can be observed where manual field observers could not record all measures. In addition, time between frames is known allowing for precise timing of events.

5-16.04.02 Video Tape

A portable TV camera with a tape recorder is often used for filming traffic situations. The tape can be recorded either in time-lapse or in real-time. Video tape has the advantage of being immediately available for review, and the tapes can be reused.

5-16.04.03 Twenty-Pen Recorder

The twenty-pen recorder is a moving graph recorder with 20 inked pens tracing lines and indicating the start or stop time of input signals. Typical uses include delay studies, headway studies and other cases where closely-spaced events preclude using stopwatches. By measuring the distance between marks on the paper, it is possible to determine the length of time between the marked events.

5-16.04.04 Hand-held computers

Laptop computers allow for collection and some or all processing by the same unit. For larger efforts, data can be dumped to PC or mainframe computers for full processing. Laptop units may be programmed for specific needs and situations.

5-16.04.05 Dedicated collection equipment

Several companies, e.g. Golden River, produce devices which collect certain types of data and output the data in useable form to PC's. Equipment for collecting counts, classifications, speeds and other data types is available.

5-16.04.06 Hand-held counters

Simple counters are available for counting cars, automobile occupancies etc. These counters merely increment by 1 each time the button is pushed.

5-16.04.07 Audio tape recorders

Audio tape recorders greatly simplify some sorts of data collection, as well as reduce collection personnel needs. Recording license plates or taking travel times are two common uses of this equipment.

5-16.04.08 Computer collection

Various types of data can be collected directly by computer where data is desired on a traffic managed segment of roadway. In addition, other equipment housed at or operated from TMC can be used for exceptional data collection efforts.

5-16.04.09 Wrong-way movement counter

A portable wrong-way movement recorder is available. This device records the number of wrong-way movements and takes a picture of each wrong-way vehicle for verification.

5-17.00 BENEFIT/COST ANALYSIS

The ratio of dollar value of benefits to dollar value of costs is often used in state or federal project planning and evaluation. It is not necessarily the best method of assessing the monetary merits of a project, but it is widely accepted and used in the field of transportation, and so is briefly reviewed here.

The basic idea behind Benefit/Cost (B/C) analysis is that if the dollar value of benefits is larger than the dollar value of costs, this ratio will be greater than 1. If the dollar value of costs is greater, the ratio will be less than 1. The exact value of B/C is not important, only whether it is greater or less than 1. If B/C is greater than 1, the project will MAKE money and so should be pursued. Dollar values for benefits or costs should be on the basis of either present-worth (PW) or equivalent uniform annual cost (EUAC).

A problem often arises, namely where to put dollar "costs" that do not involve construction maintenance etc. but are rather "costs" incurred by the public by a store owner whose business volume is reduced by a new roadway, or by the farmer who loses arable land to high voltage towers. These costs may be considered disbenefits. Both benefits and disbenefits are directly received or lost by the public. Costs, on the other hand, are paid by the government. Thus, the refined formula is more correctly:

$$B/C = \frac{\text{benefits - disbenefits}}{\text{costs}}$$

To compare projects which are not mutually exclusive (i.e. they all may be pursued), all that is necessary is to compute an individual B/C for each. Any project with B/C >1 should be undertaken.

If projects are mutually exclusive (i.e. only one can be pursued) then two criteria should be met:

1. Projects compared must have individual B/C's >1

and

2. the project selected must have an incremental B/C >1 relative to the nearest (or only) competitor.

An incremental B/C is merely a B/C created using differences in benefits, disbenefits and costs between two projects:

$$B/C = \frac{\Delta \text{ benefits - } \Delta \text{ disbenefits}}{\text{costs}}$$

5-18.00 REFERENCES

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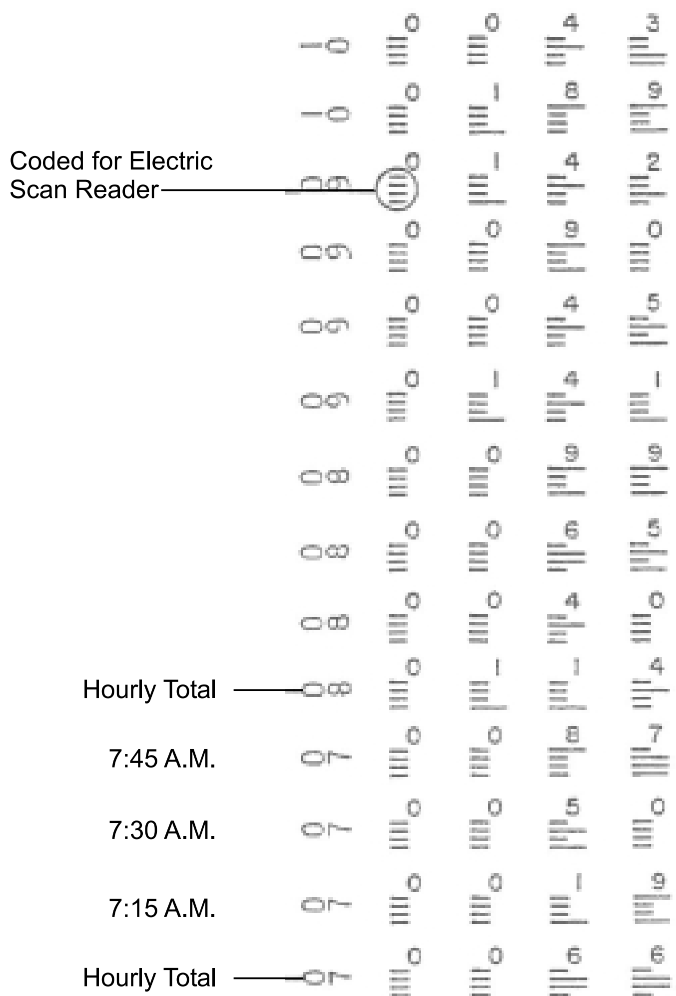
PORTABLE TRAFFIC RECORDER PRINTER TAPE

MR TAPE - Machine or Manual



Binary Traffic Count on
24-hour Clock

Text Ref.: 5-3.03.02

July 1,1991	**PORTABLE TRAFFIC RECORDER PRINTER TAPE**	FIGURE 5.1

S.P. : 6211 T.H. : 36 DATE : SEPT. 24, 1986
LOCATION: TH36 & ENGLISH

	FROM: EAST			FROM: SOUTH			FROM: WEST			FROM: NORTH			TOTAL
	TO: NORTH	TO: WEST	TO: SOUTH	TO: EAST	TO: NORTH	TO: WEST	TO: SOUTH	TO: EAST	TO: NORTH	TO: WEST	TO: SOUTH	TO: EAST	
	A 1	B 2	C 3	D 4	L 5	F 6	G 7	H 8	J 9	K 10	L-11	M-12	
6:00 615	6	212	2	0	2	36	2	70	3	2	0	2	337
6:15-6:30	15	395	5	0	4	49	5	106	7	1	0	2	589
6:30-6:45	6	544	0	3	1	58	5	135	4	5	0	0	761
6:45-7:00	14	522	9	3	4	53	8	236	9	3	2	2	865
7:00-7:15	13	626	5	6	6	57	10	235	10	6	2	1	977
7:15-7:30	22	624	4	21	3	43	16	348	17	6	0	6	1110
7:30-7:45	8	612	10	11	4	39	18	333	9	9	0	7	1080
7:45 8:00	22	530	11	7	7	51	31	331	12	7	2	3	1014
8:00-8:15	9	417	7	8	2	44	16	261	9	7	0	1	781
8:15-8:30	5	369	10	9	3	29	22	275	10	4	1	3	740
8:30 8:45	5	314	8	9	3	29	17	240	6	10	4	2	647
8:45-9:00	2	262	11	11	1	35	24	241	4	12	8	9	620
A.M. TOTAL	**127**	**5427**	**82**	**88**	**40**	**523**	**174**	**2811**	**100**	**72**	**19**	**38**	**9501**
3:00 3:15	4	292	10	9	4	34	38	373	7	16	2	9	798
3:15-3:30	5	295	17	8	1	30	45	412	13	5	1	5	837
3:30 3:45	7	392	15	9	4	38	42	502	10	17	9	14	1059
3:45-4:00	7	338	16	9	3	46	53	585	10	12	4	4	1087
4:00-415	3	284	20	12	4	43	49	507	8	33	6	17	986
4:15-4:30	9	300	19	16	2	26	40	564	8	8	1	5	986
4:30-4:45	4	347	19	14	3	50	45	587	5	13	3	8	1098
4:45 5:00	5	379	22	11	0	33	44	671	4	16	1	6	1192
5:00-5:15	5	400	18	13	0	49	50	608	6	18	6	9	1182
5:15-5:30	3	345	19	16	2	31	42	654	2	8	2	8	1132
5:30 5:45	3	323	16	14	1	36	56	555	6	10	1	6	1027
5:45-6:00	6	302	12	8	8	31	41	436	6	8	3	4	865
P.M. TOTAL	**61**	**3997**	**203**	**139**	**32**	**447**	**545**	**6454**	**85**	**164**	**39**	**95**	**12261**
TOTAL	**188**	**9424**	**285**	**227**	**72**	**970**	**719**	**9265**	**185**	**236**	**58**	**133**	**21762**

Text Ref.: 5-3.03.03

July 1,1991	**FIFTEEN MINUTE INTERSECTION COUNTS**	FIGURE 5.2

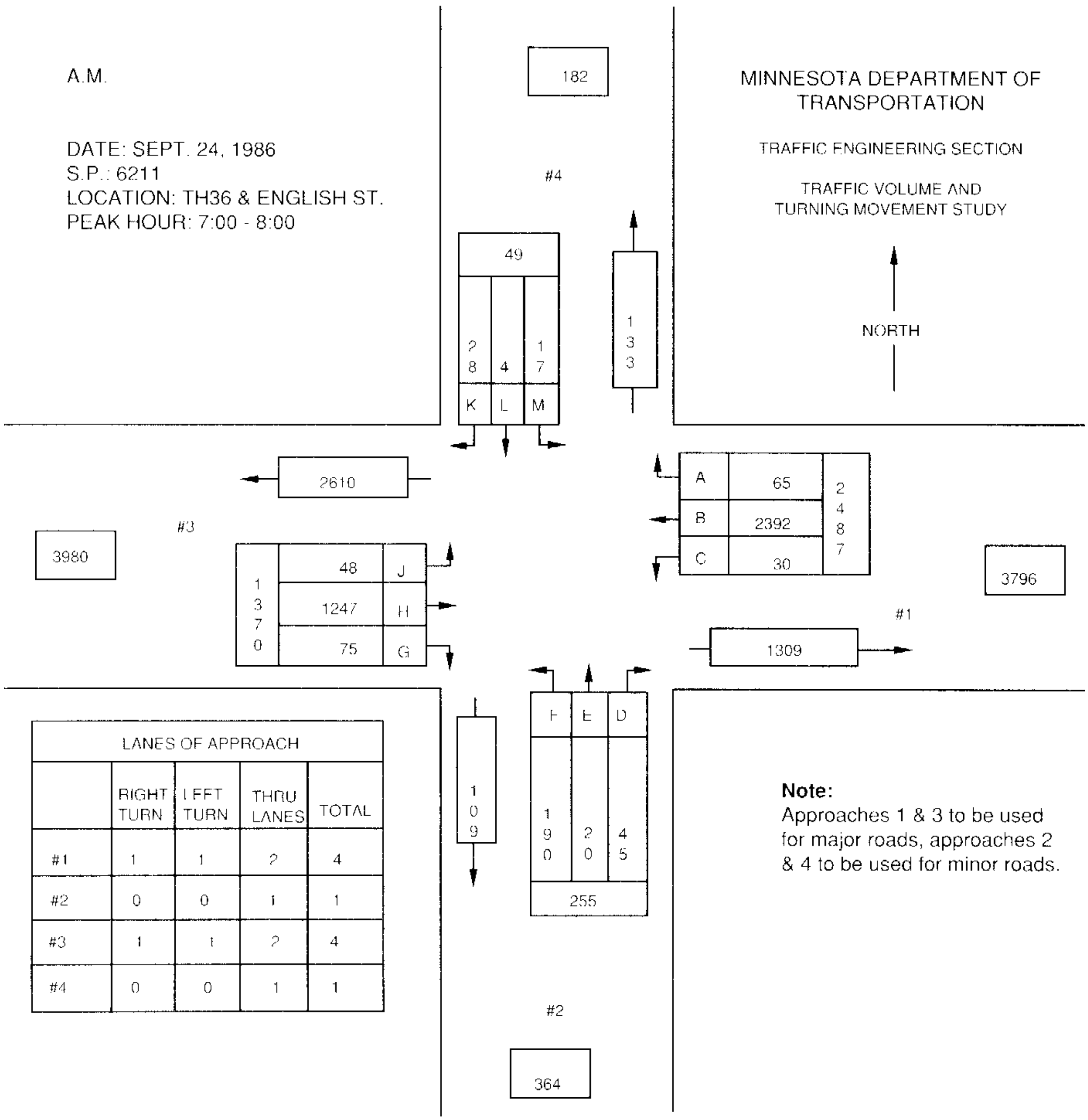
A.M.

DATE: SEPT. 24, 1986
S.P.: 6211
LOCATION: TH36 & ENGLISH ST.
PEAK HOUR: 7:00 - 8:00

MINNESOTA DEPARTMENT OF TRANSPORTATION

TRAFFIC ENGINEERING SECTION

TRAFFIC VOLUME AND TURNING MOVEMENT STUDY

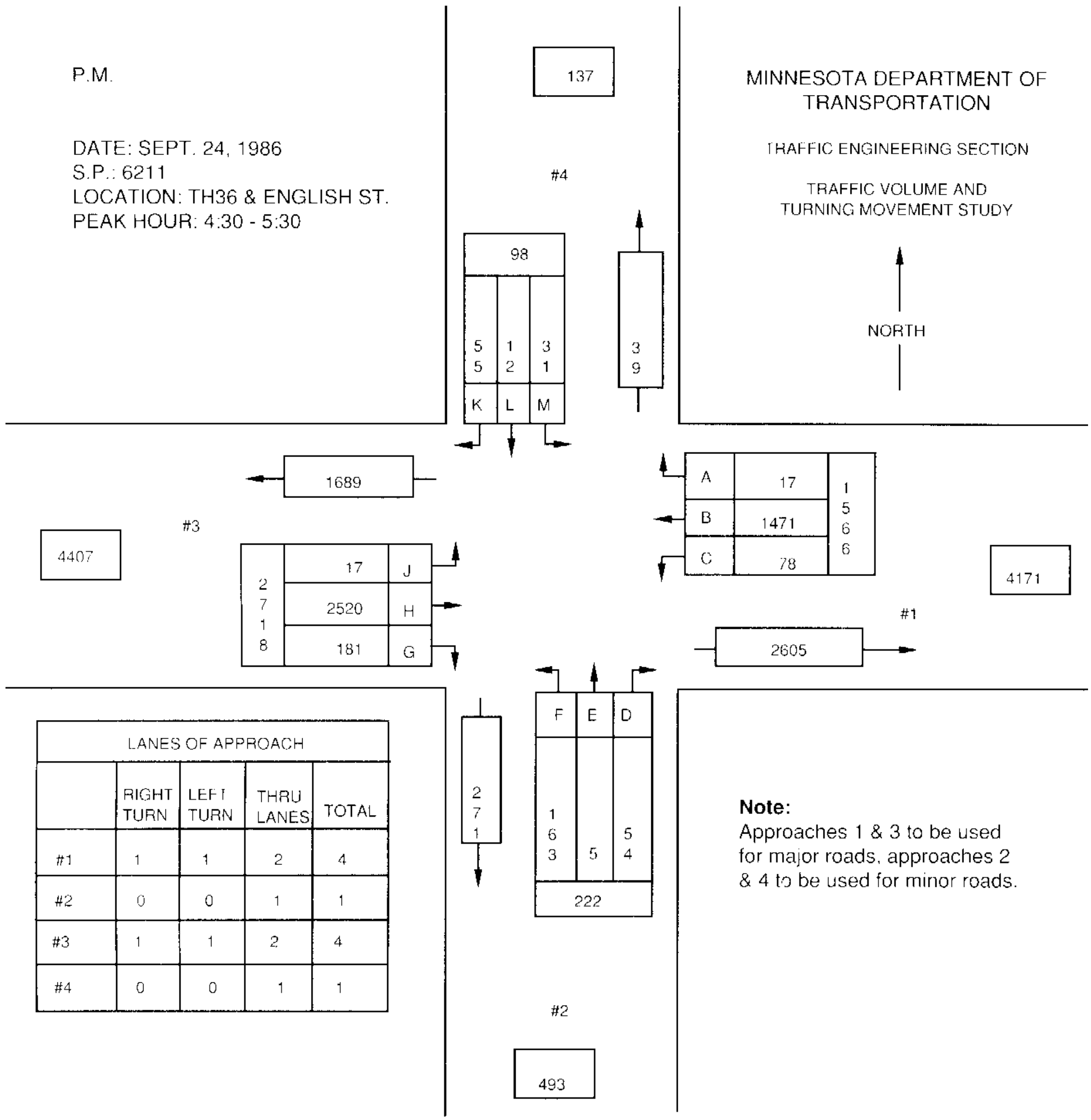


LANES OF APPROACH				
	RIGHT TURN	LEFT TURN	THRU LANES	TOTAL
#1	1	1	2	4
#2	0	0	1	1
#3	1	1	2	4
#4	0	0	1	1

Note:
Approaches 1 & 3 to be used for major roads, approaches 2 & 4 to be used for minor roads.

Text Ref.: 5-3.03.03

July 1,1991	**TRAFFIC VOLUME AND TURNING MOVEMENT STUDY (A.M.)**	FIGURE 5.3A



LANES OF APPROACH				
	RIGHT TURN	LEFT TURN	THRU LANES	TOTAL
#1	1	1	2	4
#2	0	0	1	1
#3	1	1	2	4
#4	0	0	1	1

Note:
Approaches 1 & 3 to be used for major roads, approaches 2 & 4 to be used for minor roads.

Text Ref.: 5-3.03.03

July 1,1991	**TRAFFIC VOLUME AND TURNING MOVEMENT STUDY (P.M.)**	FIGURE 5.3B

LOCATION: TH 95 NB N. of Lakeland Plaza (1st St. S.) COUNTY: Washington STATION NUMBER: 4G82

COUNT BEGINNING DATE: July 9, 1986 DATA BY: ____

DATE	14	15	9	10	11	12	13	AVERAGE of COUNT		
DAY	MON	TUE	WED	THUR	FRI	SAT	SUN	WEEKDAY	WEEKEND	
12-1AM	10	28		32	23	59	55	23	57	
1 - 2	24	15		17	16	37	60	18	48	
2 - 3	4	4		4	14	25	22	6	23	
3 - 4	8	4		8	1	12	13	5	12	
4 - 5	10	13		13	16	13	9	13	11	
5 - 6	58	69		56	44	22	19	56	20	
6 - 7	228	237		199	195	77	37	214	57	
7 - 8	316	316		354	305	109	52	322	80	
8 - 9	246	233		245	253	179	110	244	144	
9 - 10	230	204		205	208	262	147	211	204	
10 - 11	221	217		240	208	310	190	221	250	
11-12N	227	222		232	244	303	304	231	303	
12 - 1	259	211	235	246	242	254	254	238	254	
1 - 2	235		236	257	261	252	267	247	259	
2 - 3	226		252	286	283	270	272	261	271	
3 - 4	242		297	235	246	242	261	255	251	
4 - 5	302		314	254	285	225	251	288	238	
5 - 6	320		339	312	267	222	234	309	228	
6 - 7	263		320	265	347	246	254	298	250	
7 - 8	251		223	250	236	211	259	240	235	
8 - 9	167		247	192	218	224	190	206	207	
9 - 10	140		157	142	161	131	220	150	175	
10 - 11	109		136	114	137	117	137	124	127	
11-12M	60		82	54	83	92	58	69	75	
TOTAL	4156	1773	2838	4212	4293	3894	3675	4258	3784	

SKETCH

N

AVERAGE DAILY TRAFFIC

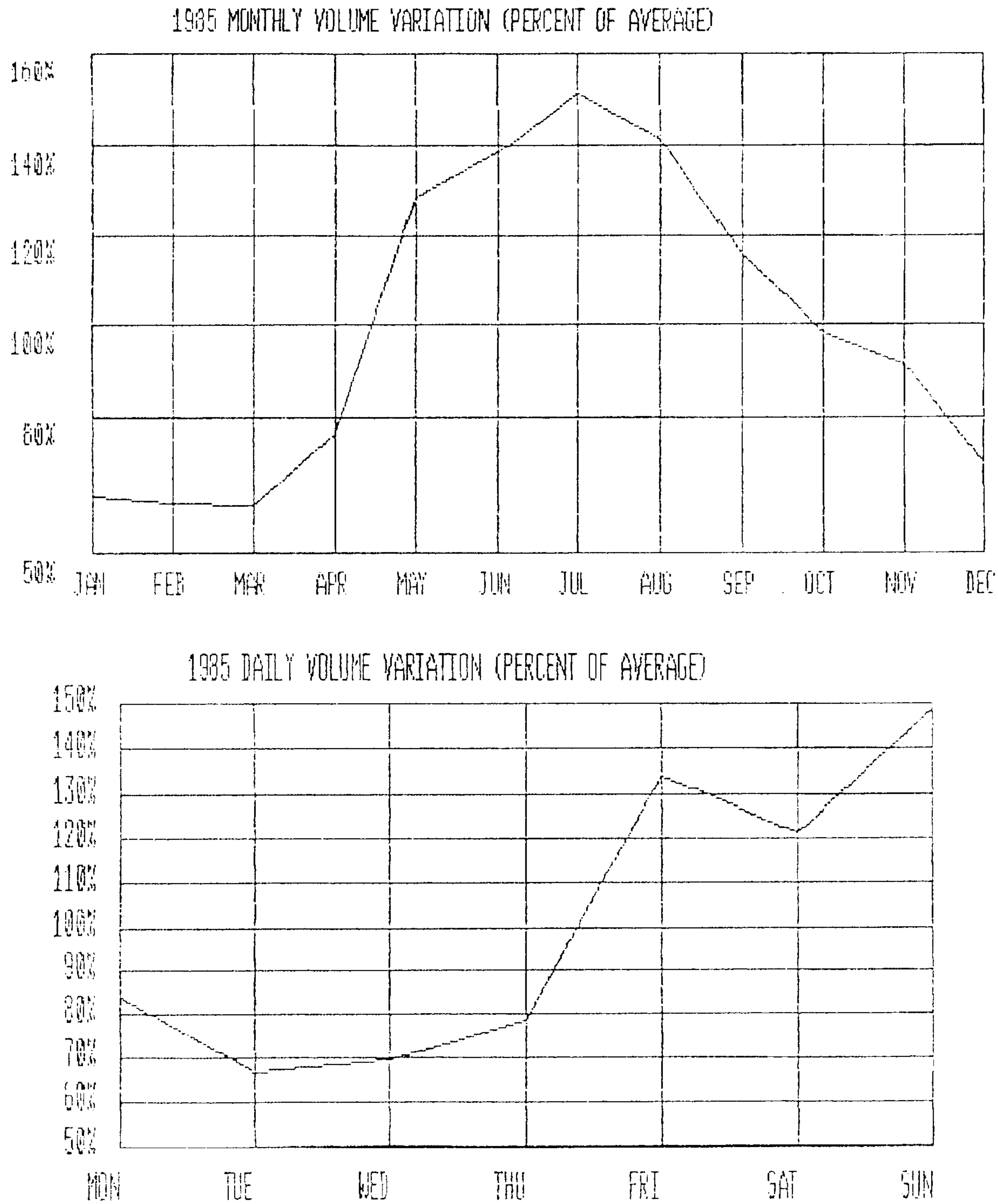
Remarks: 24 hour factor: 0.897
ADT: 3819

Recorder Type: HR ☐ MR ☐ AR ☐

Machine No. ____ Tape No. ____ File No. ____

Text Ref.: 5-3.05.01

July 1,1991	**PORTABLE TRAFFIC RECORDER DATA**	FIGURE 5.4

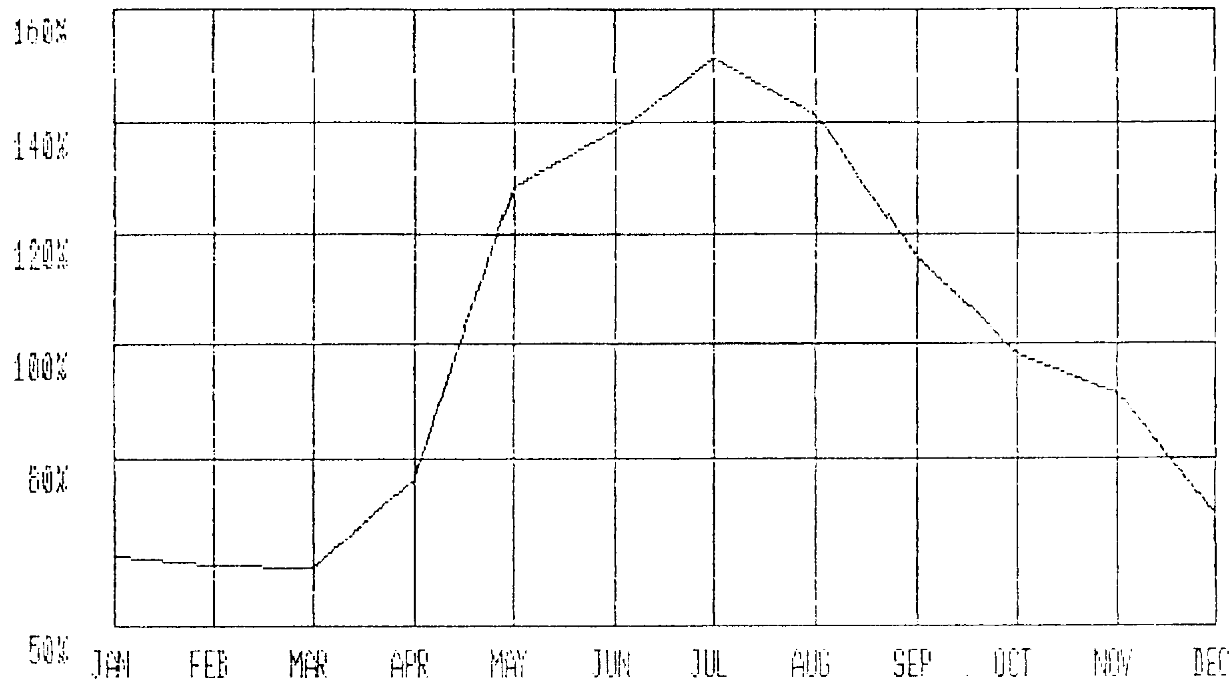


STATION 2040 TH-169, .3 MI. S OF ONAMIA.....MILLE LACS CO.

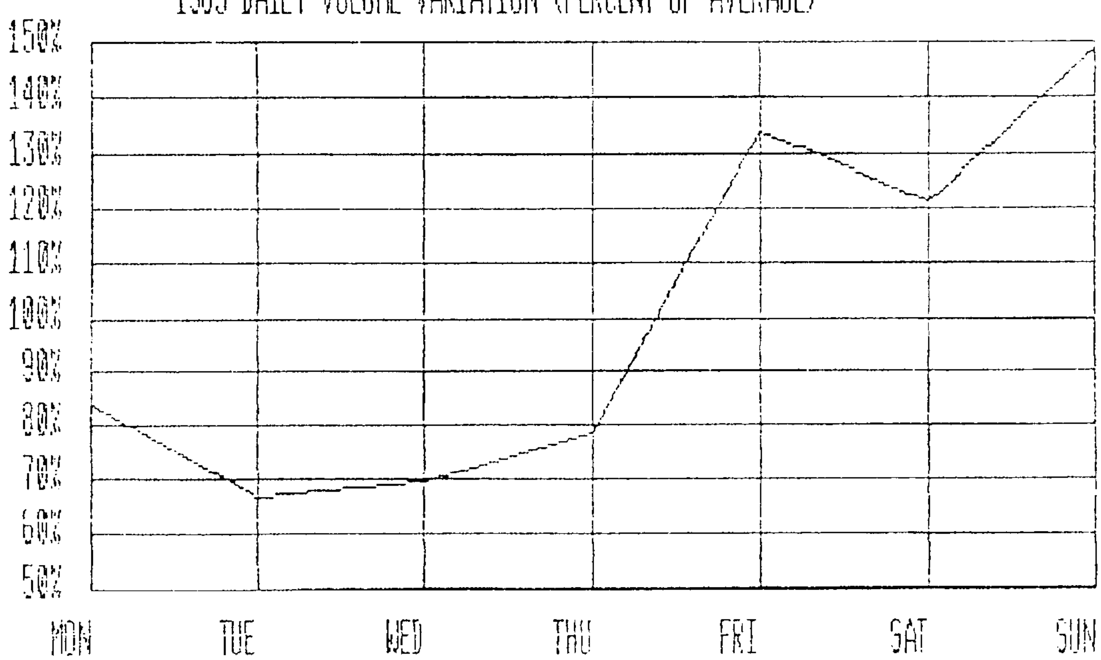
Text Ref.: 5-3.07.04

July 1,1991	**SUMMARY OF AUTOMATIC TRAFFIC RECORDER DATA**	FIGURE 5.5B

1985 MONTHLY VOLUME VARIATION (PERCENT OF AVERAGE)



1985 DAILY VOLUME VARIATION (PERCENT OF AVERAGE)



STATION 2040 TH-169, .3 MI. S OF ONAMIA.....MILLE LACS CO.

Text Ref.: 5-3.07.04

July 1,1991	**SUMMARY OF AUTOMATIC TRAFFIC RECORDER DATA**	FIGURE 5.5C

AUTOMATIC TRAFFIC RECORDER DATA
SUMMARY OF HOURLY VOLUMES FOR HIGHEST HOURS

Location: Scl of Onamia
County: Mille Lacs
Annual Daily Average: 04423

ATR Station 204
Route TH 169

Highest Hour	Traffic Volume	Date	Day	Hour	Percent of Annual Daily Average
01	1740	07-07	SUN	11-12 AM	39.3
02	1320	05-27	MON	04-05 PM	29.8
03	1210	09-02	MON	02-03 PM	27.4
04	1200	05-27	MON	03-04 PM	27.1
05	1180	05-27	MON	05-06 PM	26.7
06	1180	09-02	MON	12-01 PM	25.3
07	1150	09-02	MON	01-02 PM	26.0
08	1120	07-07	SUN	12-01 PM	25.3
09	1120	08-11	SUN	05-06 PM	25.3
10	1110	07-28	SUN	06-07 PM	25.1
11	1100	07-07	SUN	03-04 PM	24.9
12	1090	07-07	SUN	04-05 PM	24.6
13	1090	09-02	MON	11-12 AM	24.6
14	1070	07-07	SUN	06-07 PM	24.2
15	1070	09-02	MON	03-04 PM	24.2
16	1060	07-07	SUN	02-03 PM	24.0
17	1050	07-21	SUN	06-07 PM	23.7
18	1050	07-28	SUN	05-06 PM	23.7
19	1040	05-27	MON	06-07 PM	23.5
20	1040	07-21	SUN	05-06 PM	23.5
21	1040	08-11	SUN	06-07 PM	23.5
22	1030	05-19	SUN	04-05 PM	23.3
23	1030	06-16	SUN	06-07 PM	23.3
24	1030	07-07	SUN	01-02 PM	23.3
25	1020	07-28	SUN	04-05 PM	23.1
26	1020	08-04	SUN	05-06 PM	23.1
27	1010	06-16	SUN	05-06 PM	22.8
28	1010	07-07	SUN	05-06 PM	22.8
29	1010	08-11	SUN	04-05 PM	22.8
30	1010	08-18	SUN	04-05 PM	22.8
40	970	07-07	SUN	07-08 PM	21.9
50	950	06-21	FRI	08-09 PM	21.5
60	940	08-31	SAT	11-12 AM	21.3
80	900	08-18	SUN	02-03 PM	20.3
100	860	09-29	SUN	05-06 PM	19.4
130	830	08-30	FRI	08-09 PM	18.8
500	550	07-07	SUN	09-10 PM	12.4
1000	380	08-08	THUR	01-02 PM	8.6

Text Ref.: 5-3.07.04

July 1,1991	SUMMARY OF AUTOMATIC TRAFFIC RECORDING DATA	FIGURE 5.5D

AUTOMATIC TRAFFIC RECORDER DATA
SUMMARY OF YEARLY HOURLY AVERAGES

Location: Scl of Onamia
County: Mille Lacs

ATR Station 204
Route TH 169

Hour	Average Saturday By Hour		Average Sunday By Hour		Average Weekday By Hour		Average Weekday Jun-Aug By Hour		Average Day By Hour	
Time	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
AM										
MID-01	75	1.4	50	0.8	24	0.6	40	0.8	35	0.8
01-02	56	1.0	36	0.6	14	0.4	23	0.4	23	0.5
02-03	34	0.6	21	0.3	9	0.2	13	0.2	15	0.3
03-04	27	0.5	13	0.2	10	0.3	14	0.3	13	0.3
04-05	33	0.6	13	0.2	23	0.6	26	0.5	23	0.5
05-06	52	1.0	22	0.3	45	1.2	52	1.0	43	1.0
06-07	97	1.8	41	0.6	74	1.9	95	1.8	72	1.6
07-08	166	3.1	90	1.4	133	3.5	150	2.8	131	3.0
08-09	282	5.2	145	2.2	166	4.3	208	3.9	180	4.1
09-10	400	7.4	251	3.9	207	5.4	264	5.0	240	5.4
10-11	472	8.8	350	5.4	245	6.4	331	6.2	292	6.6
11-noon	484	9.0	439	6.8	263	6.9	369	6.9	320	7.2
PM										
Noon-01	441	8.2	455	7.0	263	6.9	369	6.9	316	7.1
01-02	402	7.5	477	7.4	270	7.1	372	7.0	318	7.2
02-03	380	7.1	537	8.3	282	7.4	376	7.1	332	7.5
03-04	349	6.5	578	8.9	287	7.5	383	7.2	337	7.6
04-05	320	6.0	626	9.6	298	7.8	392	7.4	348	7.9
05-06	303	5.6	624	9.6	285	7.4	384	7.2	336	7.6
06-07	257	4.8	563	8.7	246	6.4	346	6.5	293	6.6
07-08	238	4.4	468	7.2	227	5.9	339	6.4	263	5.9
08-09	193	3.6	327	5.0	188	4.9	308	5.8	208	4.7
09-10	144	2.7	198	3.1	131	3.4	226	4.3	142	3.2
10-11	100	1.9	109	1.7	87	2.3	146	2.7	92	2.1
11-Mid	68	1.3	54	0.8	53	1.4	90	1.7	55	1.2
Total (Day)	5372		6488		3837		5312		4426	

Text Ref.: 5-3.07.04

July 1,1991	**SUMMARY OF AUTOMATIC TRAFFIC RECORDER DATA**	FIGURE 5.5E

DEPARTMENT OF TRANSPORTATION

Road No. BEAM AVE.
Ref. Pt.
County RAMSEY
Date 12-19-88
Day FRIDAY

Zone 50 M.P.H.
Time 1:00 A.M.–P.M.
Weather CLOUDY
Machine TROOPER
Observer K. DAHMEN

Location JUST EAST OF KENNARD
Road Type 4 LANE DIVIDED
E.B. 85% Tile 50 M.P.H. Pace 42 to 51
W.B. 85% Tile 52 M.P.H. Pace 44 to 53

	PASSENGER CARS, PICKUPS, VANS								TRUCKS & BUSES							
	EAST Bound				WEST Bound				Bound				Bound			
	VEHICLES	T.	A.T.	%	VEHICLES	T.	A.T.	%	T.&B.	T.	A.T.	%	T.&B.	T.	A.T.	%
70																
69																
68																
67																
66																
65																
64																
63																
62																
61																
60					I	1	132	100								
59																
58	I	1	154	100												
57					II	2	131	99								
56	II	2	153	99	I	1	129	98								
55	III	3	151	98	卌	5	128	97								
54	I	1	148	96	卌 III	8	123	93								
53	IIII	4	147	95	III	3	115	87								
52	IIII	4	143	93	卌 II →	7	112	85								
51	卌 I ↑	6	138	90	卌 卌 II	12	105	79								
50	卌 IIII →	9	133	86	卌 卌 I	11	93	70								
49	卌 卌 I	11	124	80	卌 卌 III	13	82	62								
48	卌 卌 II	12	113	73	卌 卌 卌 卌	20	69	52								
47	卌 卌 卌 卌 II	22	101	66	卌 卌 II	12	49	37								
46	卌 卌 III	13	79	51	卌 卌	10	37	28								
45	卌 卌 卌 II	17	66	43	卌 I	6	27	20								
44	卌 卌 卌	15	49	32	卌 III ↓	8	21	16								
43	卌 IIII	9	34	22	II	2	13	10								
42	卌 III ↓	8	26	16	卌	5	11	8								
41	III	3	17	11	卌	5	6	5								
40	卌	5	14	9	I	1	1	1								
39	IIII	4	9	6												
38	I	1	5	3												
37	II	2	4	3												
36																
35																
34																
33	I	1	2	1												
32																
31																
30																
29																
28	I	1	1	1												
27																
26																
25																
24																
23																
22																
21																
20																

Mn/DOT 21273 (9-73)

Text Ref.: 5-4.03

July 1,1991	FIELD SPEED SURVEY SHEET	FIGURE 5.6

TRAVEL TIME AND DELAY STUDY
TEST CAR TECHNIQUE
FIELD SHEET
TEST VEHICLE METHOD 1

DATE 5-10-83 WEATHER CLEAR, 70° TRIP NO. 1

ROUTE WASHINGTON - CEDAR TO 11TH DIRECTION WB

TRIP STARTED AT 4:12:33 AT S JCT (LOCATION) ______ (MILEAGE)

TRIP ENDED AT 4:14:40 AT 11TH (LOCATION) ______ (MILEAGE)

CONTROL POINTS	
LOCATION	TIME
S. JCT 12 (WASH)	0.0.
N. JCT 12	0.28
15TH	0.5
E. JCT 35	1.45
W. JCT 35	1.67
11TH	2.07

STOPS OR SLOWS		
LOCATION	SEC DELAY	CAUSE
N. JCT 12	5	S
E. JCT 35	44	S

TRIP LENGTH ______ TRIP TIME 2.07 TRAVEL SPEED ______

RUNNING TIME 1.25 STOPPED TIME 0.82 RUNNING SPEED ______

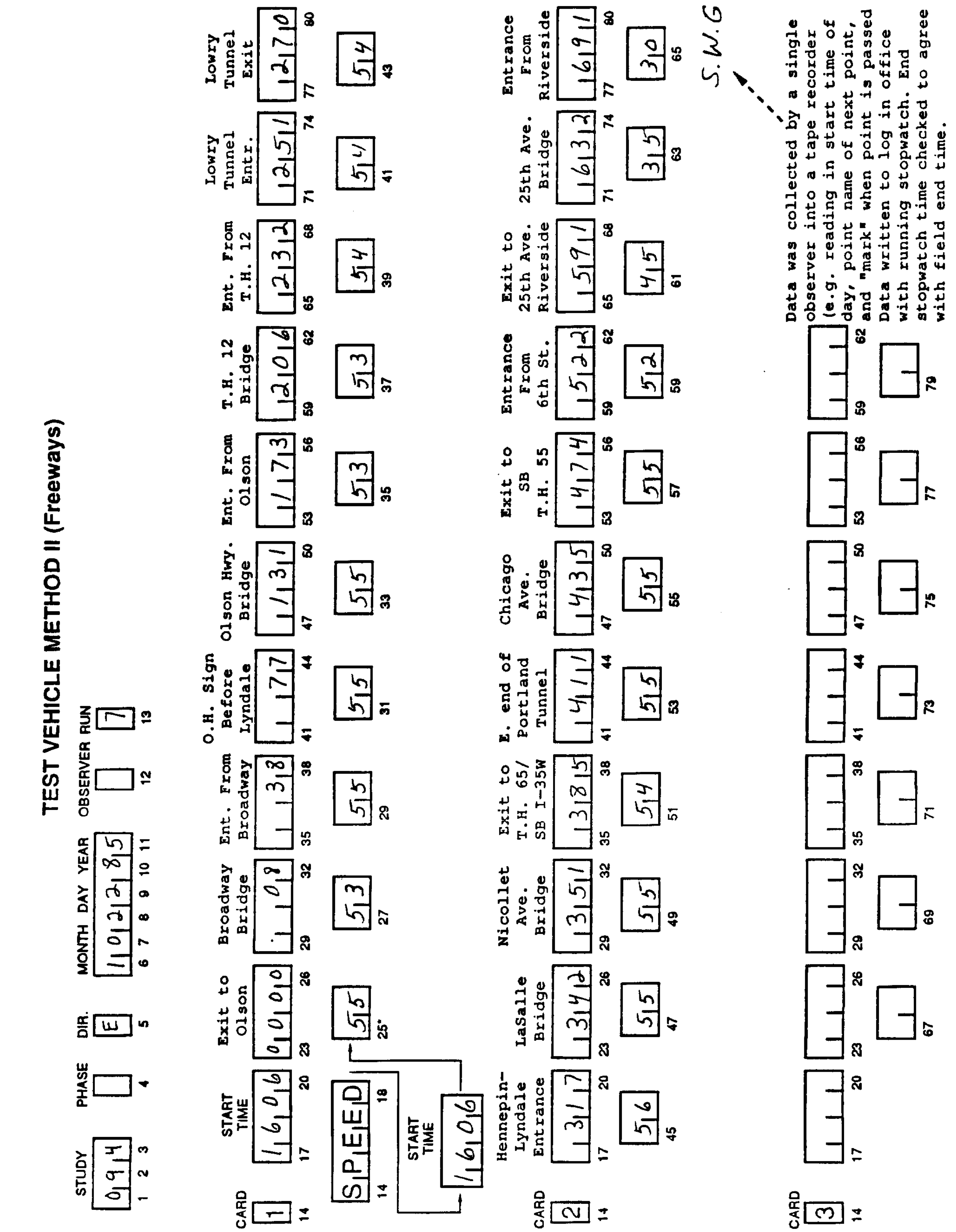
SYMBOLS OF DELAY CAUSE: S – TRAFFIC SIGNALS SS – STOP SIGN LT – LEFT TURNS
PK – PARKED CARS DP – DOUBLE PARKING T – GENERAL
PED – PEDESTRIANS BP – BUS PASSENGERS LOADING OR UNLOADING

COMMENTS ______

Text Ref.: 5-5.04

RECORDER ______

July 1,1991	TRAVEL TIME AND DELAY STUDY	FIGURE 5.7



Text Ref.: 5-5.04

July 1,1991	**TEST VEHICLE METHOD II (Freeways)**	FIGURE 5.8

TRAVEL TIME STUDY
LICENSE PLATE TECHNIQUE
FIELD SHEET

MINUTES AND SECONDS FROM START OF STUDY → 17:25
LAST THREE DIGITS OF LICENSE PLATE NUMBER → 945

LOCATION on 66TH ST. ENT. RAMP at I 35W WEATHER CLR / DRY

DATE 8-11-87 ROUTE LENGTH 1.27 MI DIRECTION OF TRAFFIC NB

TIME OF START 8 AM TIME OF END 9 AM TIME CORRECTION 0

0	1	2	3	4	5	6	7	8	9
11:15 018	8:08 112	22:17 283	11:09 216	12:15 418	27:16 501	1:17 663	11:25 716	2:21 866	15:15 976
21:15 075	20:15 183	28:17 295	29:17 332	19:16 457	29:59 524	20:53 633	19:18 741	17:12 822	17:25 945
43:03 016	32:26 143	32:16 237	32:12 325	22:15 452	31:15 594	31:17 632	21:11 719	48:17 816	28:09 918
45:19 020	43:19 175	41:15 243	44:15 313	36:41 431	31:23 507	33:14 611	36:57 771	59:43 803	35:33 917
58:52 026		52:13 217		43:36 427	48:31 512		48:19 717		36:18 905
		56:21 215		52:11 416	52:21 503				

NOTE: ONLY RECORD LAST THREE DIGITS OF LICENSE PLATE NUMBER. UNDERLINE ANY BUS OR TRUCK WITH DUAL REAR WHEELS OR HEAVIER VEHICLES

OBSERVER ____________ RECORDER ____________

Text Ref.: 5-5.04

July 1,1991	**TRAVEL TIME STUDY LICENSE PLATE TECHNIQUE**	FIGURE 5.9

ANALYSIS OF DATA FOR MOVING VEHICLE METHOD OF ESTIMATING VOLUME AND TRAVEL TIME

LINK I

S. JCT 12 — N. JCT 12

Run Number	Travel Time (in minutes)	Vehicles Met By Test Car from Opposing Direction	Vehicles Overtaking Text Car	Vehicles Passed by Test Car
bound Trips	T_n	M_n	O_n	P_n
1.	0.44		0	3
2.	0.50		0	0
3.	0.17		0	0
4.	0.27		0	9
5.	0.31		0	1
6.	0.53		0	0
Total	2.22		0	13
Average	0.37		0	2.17
bound Trips	T_s	M_s	O_s	P_s
1.	0.40	2		
2.	0.15	10		
3.	0.09	10		
4.	0.18	7		
5.	0.16	8		
6.	0.15	8		
Total	1.13	4.5		
Average	0.19	7.5		

Text Ref.: 5-5.04

July 1,1991	ESTIMATING VOLUME AND TRAVEL TIME	FIGURE 5.10

MOVING VEHICLE METHOD (Computations)

VOLUMES AND TRAVEL TIMES

Link	M_s	O_n	P_n	T_n	T_s	V_n	$\overline{T}_n$
S Jct 12 – N Jct 12	7.50	0	2.17	0.37	0.19	571	0.598
N Jct 12 – 15th Ave	12.67	1.67	2.17	0.51	0.24	983	0.539
15th Ave – E Jct 35	6.33	0.67	1.83	0.36	0.20	552	0.486
E Jct 35 – W Jct 35	3.15	0.83	1.00	0.54	0.23	232	0.583
W Jct 35 – 11th Ave	11.67	0.33	0.17	0.38	0.68	674	0.362
OVERALL:							
S Jct 12 – 11th Ave	41.67	2.83	7.33	2.16	1.53	604	2.607

NOTE: $$V_n = \frac{60(M_s + O_n - P_n)}{T_n + T_s} = \text{Veh/Hr}$$

$$\overline{T}_n = T_n - \frac{60(O_n - P_n)}{V_n} = \text{min.}$$

* Reverse subscripts for opposite direction

V_n = Northbound hourly volume

M_s = Count of vehicles met (opposing flow) while test vehicle was traveling south

O_n = Number of vehicles passing the test car (overtaking) while the test car was traveling north

P_n = Number of vehicles passed by the test car while it was traveling north

T_n = Travel time in minutes while traveling north

Text Ref.: 5-5.04

July 1,1991	**MOVING VEHICLE METHOD (Computations)**	FIGURE 5.11

INTERSECTION DELAY STUDY

FIELD SHEET

Location FIRST W.B. SIGNET AT THE INTERCHANGE W/ I-35W ON WASHINGTON Approach WEST Movement STRAIGHT + R.T.

Date MAY 19, 1983 Weather CLOUDY, DRIZZLE 50° Study No. 1 Observer ______

Time (minute starting at)	Total Number of Vehicles Stopped in the Approach at Time:				Approach Volume	
	+0 sec	+15 sec	+30 sec	+45 sec	Number Stopped	Number Not Stopping
1610	0	0	0	2	3	17
1611	2	0	0	0	2	18
1612	0	7	8	10	11	1
1613	11	20	0	10	5	7
1614	16	4	0	0	8	19
1615	0	1	2	2	4	0
1616	4	0	0	1	3	15
1617	2	5	5	13	12	0
1618	0	2	4	7	5	0
1619	7	15	3	6	13	5
1620	10	12	12	23	10	0
1621	8	5	9	9	10	0
1622	9	18	5	6	13	0
1623	7	8	10	17	9	0
1624	2	4	6	9	11	0
1625	0	0	0	2	2	13
Subtotal	78	101	64	117	121	95
Total	360				216	

Total Delay = Total Number Stopped x Sampling Interval

= 360 x 15 = 5400 veh sec

Average Delay per Stopped Vehicle = $\frac{\text{Total Delay}}{\text{Number of Stopped Vehicles}}$

= $\frac{5400}{121}$ = 44.6 sec

Average Delay per Approach Vehicle = $\frac{\text{Total Delay}}{\text{Approach Volume}}$

= $\frac{5400}{216}$ = 25.0 sec

Percent of Vehicles Stopped = $\frac{\text{Number of Stopped Vehicles}}{\text{Approach Volume}}$ = $\frac{121}{216}$ = 56.0 percent

Text Ref.: 5-5.04

July 1,1991	INTERSECTION DELAY STUDY	FIGURE 5.12

LOCATION: 6th St Exit I-94 DIRECTION: WB

OBSERVER: ______

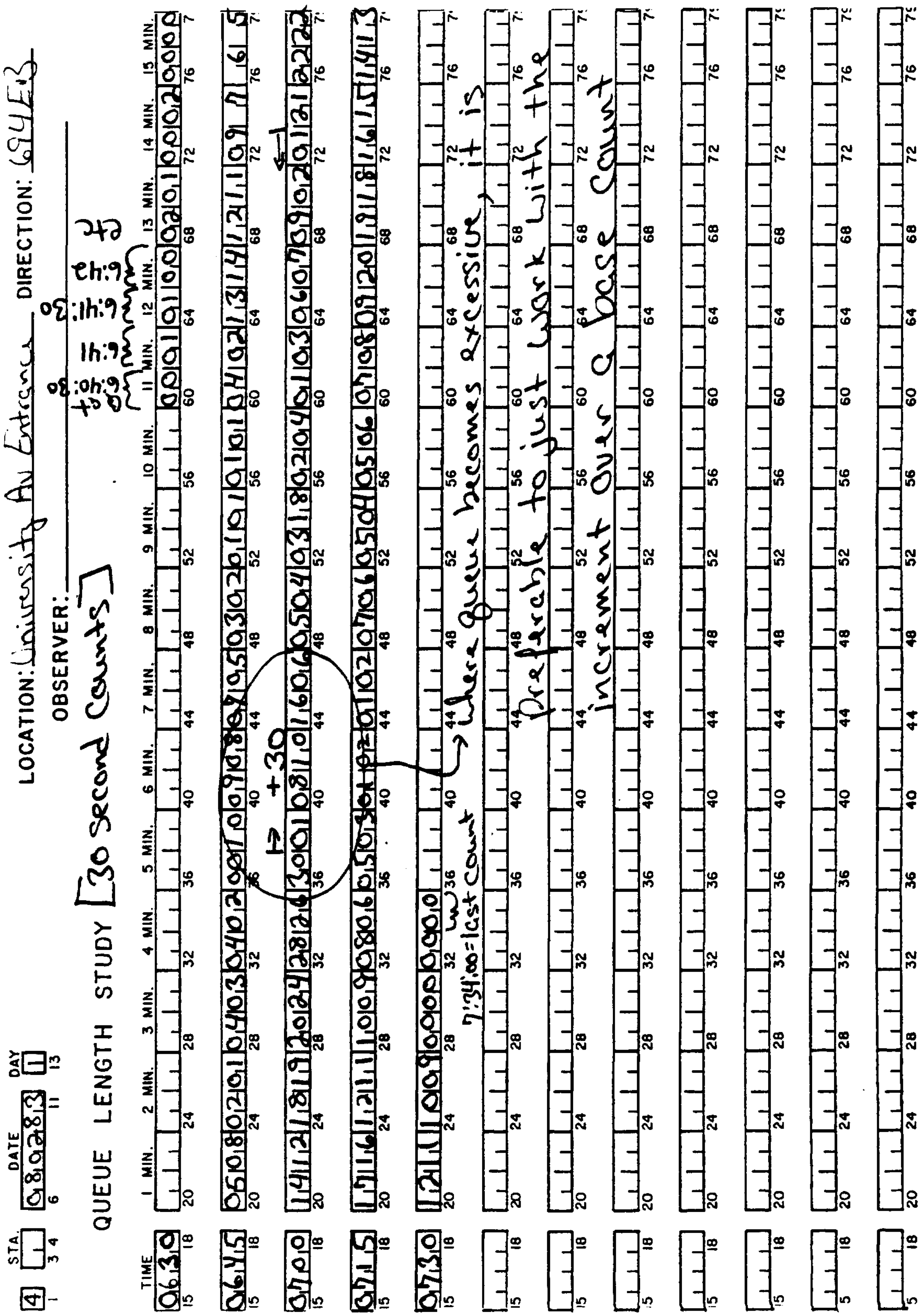
	. .E	MONTH	DATE	YEAR	DAY
03	02	03	15	76	1
1 2	4 5	7 8	9 10	11 12	13

TIME 1630 (14–17)

TIME (14–17)	1 OCCUPANT (19–23)	2 OCCUPANTS (25–29)	3 OCCUPANTS (31–35)	4 OCCUPANTS (37–41)	5 OCCUPANTS (43–47)	6 OCCUPANTS (49–53)	7 OCCUPANTS (55–59)	TRUCK (61–65)	BUS (67–71)
1645	87	41	10	1	0	0	0	1	0
1700	165	90	12	2	0	0	0	2	1
1715	246	157	19	8	1	3	2	4	2
1730	340	230	34	13	5	6	3	9	4
1745	463	301	45	24	12	8	4	14	7
1800	608	378	53	24	15	8	4	15	7
1815	709	414	56	25	15	8	4	18	9
1830	826	454	59	26	17	8	4	21	10

Text Ref.: 5-6.03

July 1,1991	**VEHICLE OCCUPANCY DATA RECORDING**	FIGURE 5.13



Text Ref.: 5-9.03

July 1,1991	**QUEUE LENGTH DATA RECORDING**	FIGURE 5.14

MHD 29165 (9-75)

VEHICLE CLASSIFICATION FORM

LOCATION NUMBER 260 DIRECTION North DATE 6-29-76 HOUR 6-7AM RECORDER J. Smith

STUDY: LOCATION NUMBER: SERIAL NUMBER — 1 | 2 3 4 | 5 6 7 8

DIRECTION — 9

YEAR: MONTH: DAY: HOUR — 10 11 | 12 13 | 14 15 | 16 17

DAY OF WEEK: CYCLE — 18 | 19

OTHER THAN HEAVY COMMERCIAL TRAFFIC
(1043)
20 21 22 23

SINGLE UNIT TRUCKS

2-AXLE 6-TIRE TRUCKS							
TANK	STAKE	REFRIG-ERATOR	VAN	DUMP	PANEL PICKUP	GRAIN BOX	CATTLE RACK
	// (2)	//// (4)	~~////~~ / (6)	~~////~~ ~~////~~ (10)	~~////~~ (5)		
24 25	26 27	28 29	30 31	32 33	34 35	36 37	38 39

3-AXLE TRUCKS							4-AXLE & +			BUSES			
TANK	STAKE	REFRIG-ERATOR	VAN	DUMP	GRAIN BOX	CATTLE RACK	TANK	DUMP	OTHER	COMM.	SCHOOL	OTHER	CARD
~~////~~ ~~////~~ / (11)	// (2)	//// (4)		~~////~~ ~~////~~ ~~////~~ ~~////~~ // (22)		/// (3)		~~////~~ //// (9)		~~////~~ /// (8)		/// (3)	1
40 41	42 43	44 45	46 47	48 49	50 51	52 53	54 55	56 57	58 59	60 61	62 63	64 65	80

TRACTOR-SEMITRAILER TRUCKS

3-AXLE SEMI			4-AXLE SEMI						5-AXLE SEMI							SIX & + AXLE SEMI
STAKE	VAN	OTHER	T	STAKE	R	VAN	CR	C	TANK	STAKE	REF.	VAN	DUMP	GRAIN BOX	CATTLE RACK	
	//// (4)			//// (4)		~~////~~ ~~////~~ (10)		// (2)	~~////~~ ~~////~~ // (12)	//// (4)	/// (3)	~~////~~ ~~////~~ ~~////~~ ~~////~~ /// (23)	~~////~~ // (7)	~~////~~ //// (9)	// (2)	//// (4)
20 21	22 23	24 25	26	27	28 29	30 31	32	33	34 35 36	37 38 39	40 41	42 43 44	45 46	47 48 49	50 51	52

TRUCK-TRAILERS		
HEAVY TRUCK W/TRAILER		
4 AXLE	5 AXLE	6&+ AXLE
// (2)	~~////~~ ~~////~~ / (11)	
53 54	55 56	57 58

TWIN TRAILERS					
5 AXLE TWIN TRAILERS				6 AXLE TW. TR.	CARD
TANK	VAN	GRAIN B.	OTHER		
// (2)	//// (4)				2
59 60	61 62	63 64	65 66	67 68	80

Text Ref.: 5-10.04

July 1,1991	VEHICLE CLASSIFICATION DATA	FIGURE 5.15

Mn/DOT 2914 (7-77)

Minnesota Department of Transportation

Sheet____ of____

TRAFFIC DENSITY STATION REPORT

County________________ District________________ Cycle ________________ Station________________ Recorder________________

I. Route ________________ Date Removed ________ Hour ______ a.m. P.m. Reading ________

Direction from Station ________ Date Set ________ Hour ______ a.m. P.m. Reading ________

Machine Number ________________ Total Hours ________________ Total Traffic ________

Machine Type ________________ 24 Hr. Traffic ________

Factor ________

Remarks:________________ A.D.T. ________

Previous Year ________

II. Route ________________ Date Removed ________ Hour ______ a.m. P.m. Reading ________

Direction from Station ________ Date Set ________ Hour ______ a.m. P.m. Reading ________

Machine Number ________________ Total Hours ________________ Total Traffic ________

Machine Type ________________ 24 Hr. Traffic ________

Factor ________

Remarks:________________ A.D.T. ________

Previous Year ________

III. Route ________________ Date Removed ________ Hour ______ a.m. P.m. Reading ________

Direction from Station ________ Date Set ________ Hour ______ a.m. P.m. Reading ________

Machine Number ________________ Total Hours ________________ Total Traffic ________

Machine Type ________________ 24 Hr. Traffic ________

Factor ________

Remarks:________________ A.D.T. ________

Previous Year ________

IV. Route ________________ Date Removed ________ Hour ______ a.m. P.m. Reading ________

Direction from Station ________ Date Set ________ Hour ______ a.m. P.m. Reading ________

Machine Number ________________ Total Hours ________________ Total Traffic ________

Machine Type ________________ 24 Hr. Traffic ________

Factor ________

Remarks:________________ A.D.T. ________

Previous Year ________

V. Route ________________ Date Removed ________ Hour ______ a.m. P.m. Reading ________

Direction from Station ________ Date Set ________ Hour ______ a.m. P.m. Reading ________

Machine Number ________________ Total Hours ________________ Total Traffic ________

Machine Type ________________ 24 Hr. Traffic ________

Factor ________

Remarks:________________ A.D.T. ________

Previous Year ________

Weather and Road Conditions:

Text Ref.: 5-3.05.01

July 1 ,1991	TRAFFIC DENSITY STATION REPORT	FORM 5.A

LOCATION: ______________ COUNTY: ______________ STATION NUMBER: ________

COUNT BEGINNING DATE: ______________ DATA BY: ______________

DATE								AVERAGE of COUNT		
DAY	MON	TUE	WED	THUR	FRI	SAT	SUN	WEEKDAY	WEEKEND	
12-1AM										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12										
12-1										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12PM										
TOTAL										

SKETCH

N

AVERAGE DAILY TRAFFIC

Remarks: ______________

Recorder Type: HR ☐ MR ☐ AR ☐

Machine No. ________ Tape No. ________ File No. ________

Text Ref.: 5-3.05.01

July 1,1991	**PORTABLE TRAFFIC RECORDER DATA**	FORM 5.B

DATE ______ DISTRICT TRAFFIC ENGINEERING STATION ______

RECORDER ______ CONSTRUCTION DIST. ______ D.T.E. ______ CITY ______

MOTOR VEHICLE TRAFFIC VOLUME AND TURNING MOVEMENT FIELD REPORT COUNTY ______

HOUR	FROM				FROM				FROM				FROM			
	To	To	To	Total	To	To	To	Total	To	To	To	Total	To	To	To	Total
6:00-6:15																
6:15-6:30																
6:30-6:45																
6:45-7:00																
7:00-7:15																
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9:15-9:30																
9:30-9:45																
9:45-10:00																
TOTAL																

Text Ref.: 5-3.05.02

REDUCED SCALE

July 1,1991	**MOTOR VEHICLE TRAFFIC VOLUME AND TURNING FIELD REPORT**	FORM 5.C

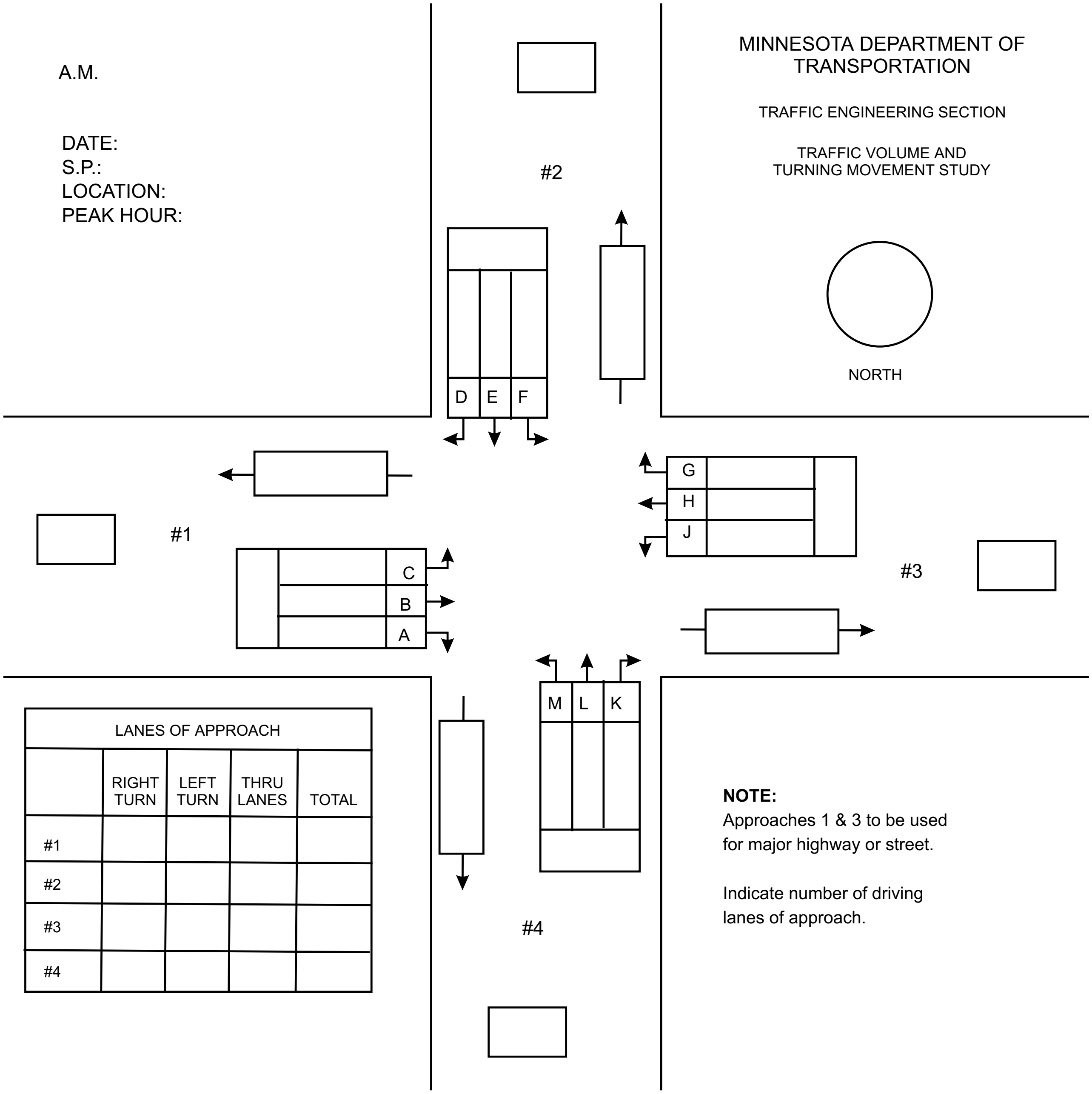
A.M.

DATE:
S.P.:
LOCATION:
PEAK HOUR:

MINNESOTA DEPARTMENT OF TRANSPORTATION

TRAFFIC ENGINEERING SECTION

TRAFFIC VOLUME AND TURNING MOVEMENT STUDY



LANES OF APPROACH				
	RIGHT TURN	LEFT TURN	THRU LANES	TOTAL
#1				
#2				
#3				
#4				

NOTE:
Approaches 1 & 3 to be used for major highway or street.

Indicate number of driving lanes of approach.

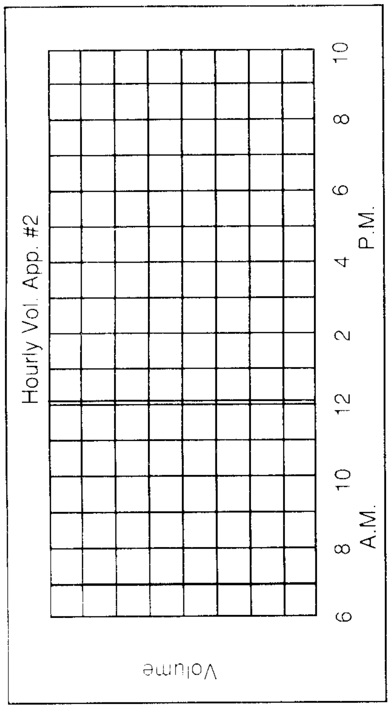
Text Ref.: 5-3.05.02

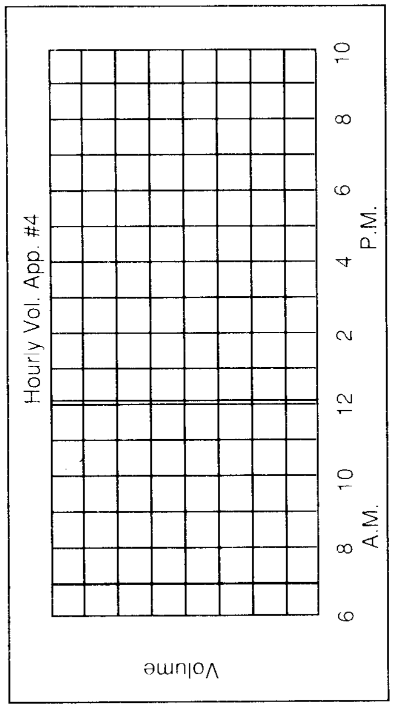
July 1,1991	**TRAFFIC VOLUME AND TURNING MOVEMENT STUDY**	FORM 5.D

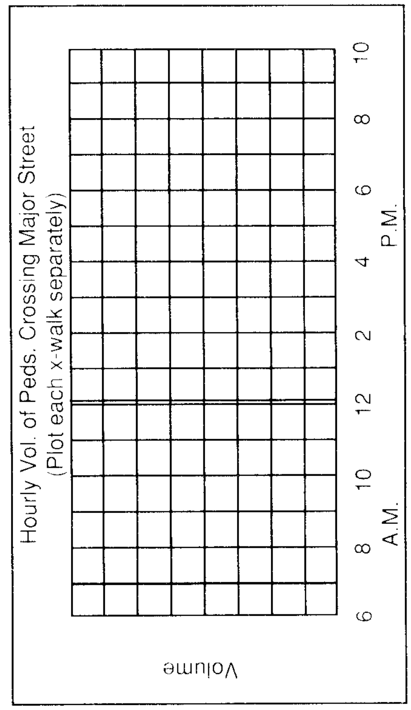
C.S. ____________________

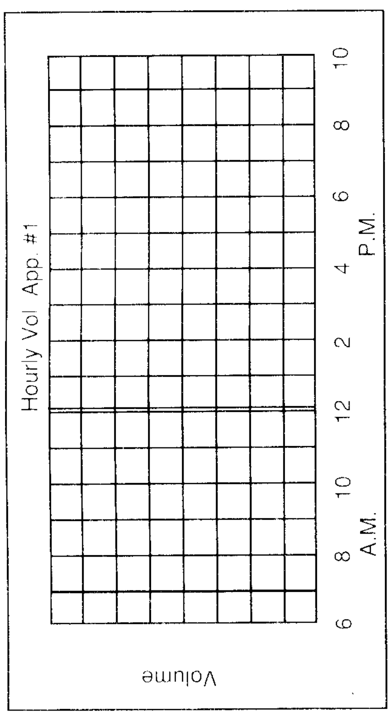
Location ____________________

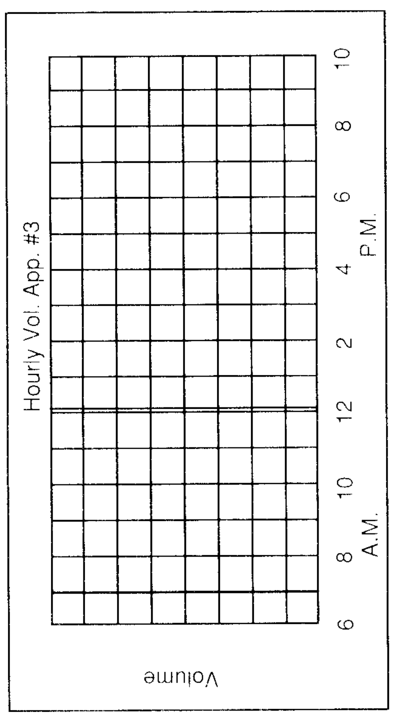
____

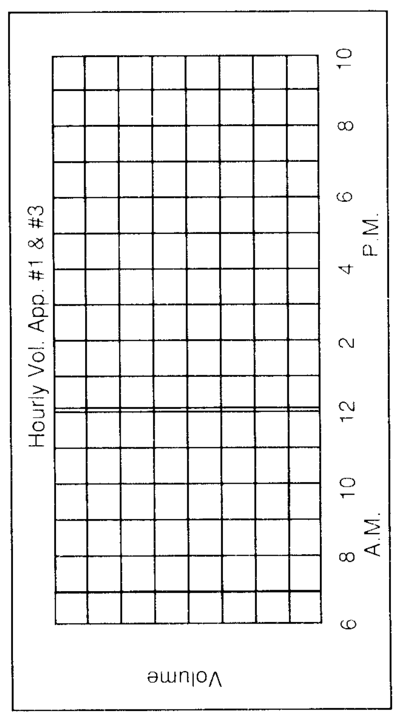












Text Ref.: 5-3.05.02

July 1,1991	**SUMMARY OF HOURLY APPROACH VOLUMES**	FORM 5.E

DEPARTMENT OF TRANSPORTATION

Road No. __________ Zone ________ M.P.H. Location __________

Ref. Pt. __________ Time ________ A.M.–P.M.

County __________ Weather ________ Road Type __________

Date __________ Machine ________ ___.B. 85% Tile ______ M.P.H. ___Pace ___to ___

Day __________ Observer ________ ___.B. 85% Tile ______ M.P.H. ___Pace ___to ___

	PASSENGER CARS, PICKUPS, VANS								TRUCKS & BUSES							
		Bound				Bound				Bound				Bound		
	VEHICLES	T.	A.T.	%	VEHICLES	T.	A.T.	%	T.&B.	T.	A.T.	%	T.&B.	T.	A.T.	%
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Mn/DOT 21273 (9-73)

Text Ref.: 5-4.03

July 1,1991	**FIELD SPEED SURVEY SHEET**	FORM 5.F

TRAVEL TIME AND DELAY STUDY
TEST CAR TECHNIQUE
FIELD SHEET
TEST VEHICLE METHOD 1

DATE ________ WEATHER ________ TRIP NO. ________

ROUTE ________ DIRECTION ________

TRIP STARTED AT ________ AT ________ (LOCATION) ________ (MILEAGE)

TRIP ENDED AT ________ AT ________ (LOCATION) ________ (MILEAGE)

CONTROL POINTS	
LOCATION	TIME

STOPS OR SLOWS		
LOCATION	SEC DELAY	CAUSE

TRIP LENGTH ________ TRIP TIME ________ TRAVEL SPEED ________

RUNNING TIME ________ STOPPED TIME ________ RUNNING SPEED ________

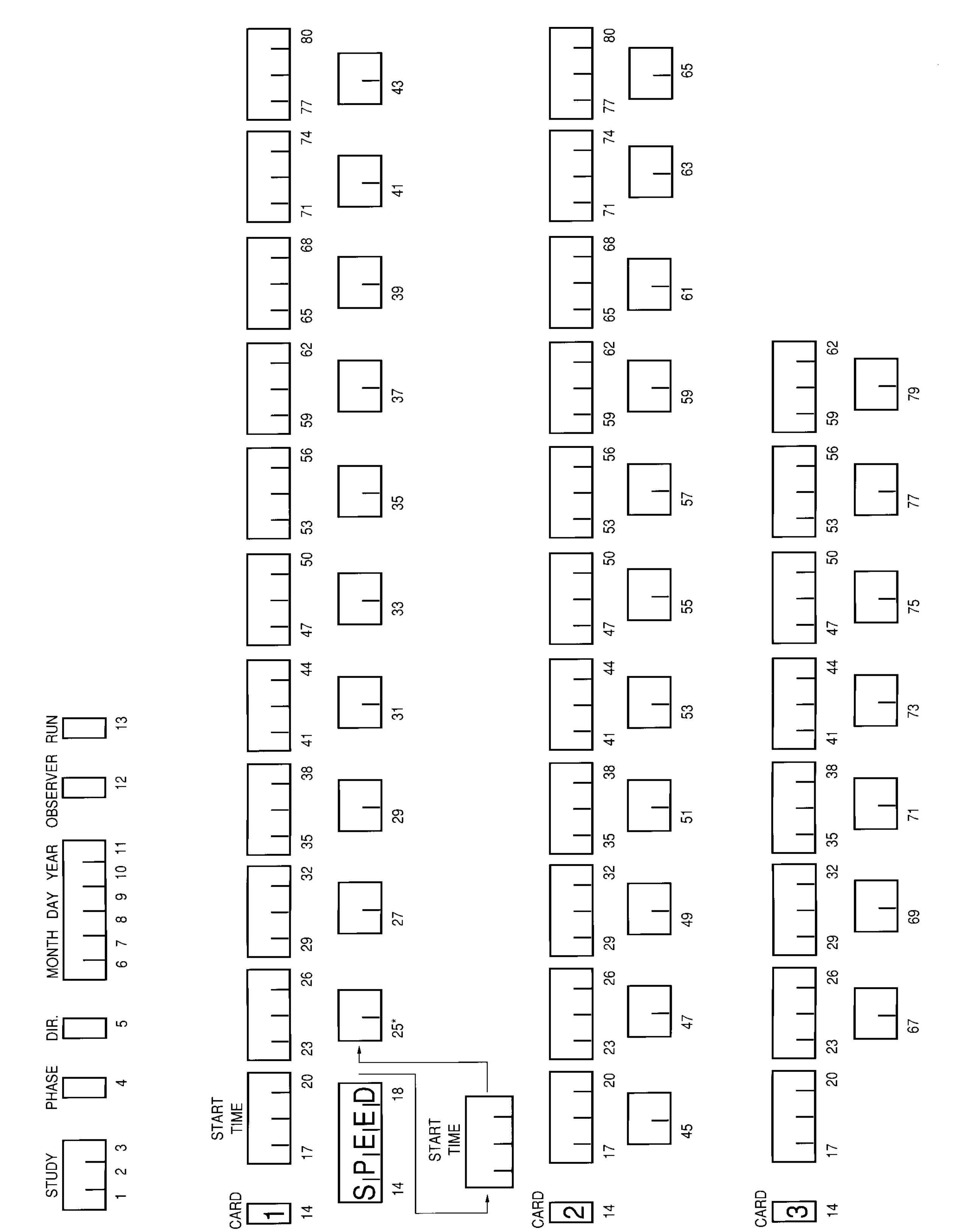
SYMBOLS OF DELAY CAUSE: S – TRAFFIC SIGNALS, SS – STOP SIGN, LT – LEFT TURNS
PK – PARKED CARS, DP – DOUBLE PARKING, T – GENERAL
PED – PEDESTRIANS, BP – BUS PASSENGERS LOADING OR UNLOADING

COMMENTS ________

Text Ref.: 5-5.04

RECORDER ________

July 1, 1991	TRAVEL TIME AND DELAY STUDY	FORM 5.G



Text Ref.: 5-5.04

July 1,1991	**TEST VEHICLE METHOD II (Freeways)**	FORM 5.H

TRAVEL TIME STUDY
LICENSE PLATE TECHNIQUE
FIELD SHEET

LOCATION or ______________ at ______________ WEATHER ______________

DATE ______________ ROUTE LENGTH ______________ DIRECTION OF TRAFFIC ______________

TIME OF START ______________ TIME OF END ______________ TIME CORRECTION ______________

0	1	2	3	4	5	6	7	8	9

NOTE: ONLY RECORD LAST THREE DIGITS OF LICENSE PLATE NUMBER. UNDERLINE ANY BUS OR TRUCK WITH DUAL REAR WHEELS OR HEAVIER VEHICLES

Text Ref.: 5-5.04

OBSERVER ______________ RECORDER ______________

July 1, 1991	TRAVEL TIME STUDY LICENSE PLATE TECHNIQUE	FORM 5.I

ANALYSIS OF DATA FOR MOVING VEHICLE METHOD OF ESTIMATING VOLUME AND TRAVEL TIME

Run Number	Travel Time (in minutes)	Vehicles Met By Test Car from Opposing Direction	Vehicles Overtaking Text Car	Vehicles Passed by Test Car
bound Trips	T_n	M_n	O_n	P_n
1.				
2.				
3.				
4.				
5.				
6.				
Total				
Average				
bound Trips	T_s	M_s	O_s	P_s
1.				
2.				
3.				
4.				
5.				
6.				
Total				
Average				

Text Ref.: 5-5.04

July 1,1991	ESTIMATING VOLUME AND TRAVEL TIME	FORM 5.J

INTERSECTION DELAY STUDY

FIELD SHEET

Location ______________________ Approach ______________ Movement ________

Date __________ Weather ______________ Study No. __________ Observer __________

Time (minute starting at)	Total Number of Vehicles Stopped in the Approach at Time:				Approach Volume	
	+0 sec	+15 sec	+30 sec	+45 sec	Number Stopped	Number Not Stopping
Subtotal						
Total						

Total Delay = Total Number Stopped x Sampling Interval

= __________ x 15 = __________ veh-sec

Average Delay per Stopped Vehicle = $\frac{\text{Total Delay}}{\text{Number of Stopped Vehicles}}$

= ______________ = ______________ sec

Average Delay per Approach Vehicle = $\frac{\text{Total Delay}}{\text{Approach Volume}}$

= ______________ = ______________ sec

Percent of Vehicles Stopped = $\frac{\text{Number of Stopped Vehicles}}{\text{Approach Volume}}$ = __________ = ______ percent

Text Ref.: 5-5.04

July 1, 1991	INTERSECTION DELAY STUDY	FORM 5.K

LOCATION: ______________ DIRECTION: ______________

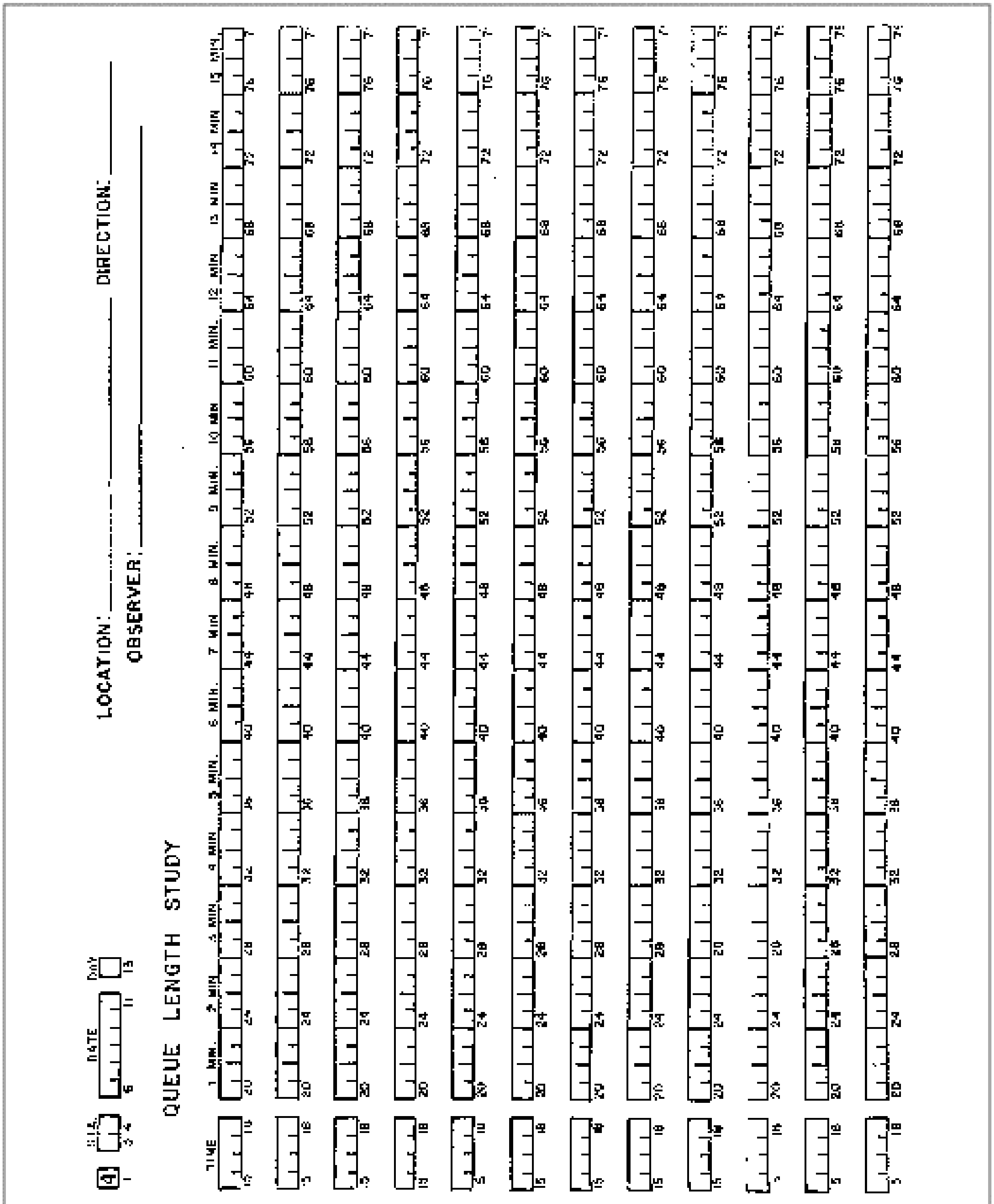
OBSERVER: ______________

0 3	..E	MONTH	DATE	YEAR	DAY
1 2	4 5	7 8	9 10	11 12	13

TIME	1 OCCUPANT	2 OCCUPANTS	3 OCCUPANTS	4 OCCUPANTS	5 OCCUPANTS	6 OCCUPANTS	7 OCCUPANTS	TRUCK	BUS
14 17									
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71
14 17	19 23	25 29	31 35	37 41	43 47	49 53	55 59	61 65	67 71

Text Ref.: 5-6.03

July 1,1991	**VEHICLE OCCUPANCY DATA RECORDING FORM**	FORM 5.L



Text Ref.: 5-9.03

July 1, 1991	**QUEUE LENGTH DATA RECORDING FORM**	FORM 5.M

Mn/DOT 29165 (1-77)

VEHICLE CLASSIFICATION FORM

LOCATION NUMBER ______ DIRECTION ______ DATE ______ HOUR ______ RECORDER ______

STUDY: LOCATION NUMBER: SERIAL NUMBER — — — — — — — — 1 | 2 3 4 | 5 6 7 8

DIRECTION — 9

YEAR: MONTH: DAY: HOUR — — — — — — — — — — — — — 10 11 | 12 13 | 14 15 | 16 17

DAY OF WEEK: CYCLE — — — — — — — — — — — — — — — — — — 18 | 19

(0)

OTHER THAN HEAVY COMMERCIAL TRAFFIC			
20	21	22	23

SINGLE UNIT TRUCKS (1)

2-AXLE 6-TIRE TRUCKS															
TANK		STAKE		REFRIG-ERATOR		VAN		DUMP		PANEL PICKUP		GRAIN BOX		CATTLE RACK	
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39

(2) (2) (6)

3-AXLE TRUCKS														4-AXLE & +						BUSES						CARD
TANK		STAKE		REFRIG-ERATOR		VAN		DUMP		GRAIN BOX		CATTLE RACK		TANK		DUMP		OTHER		COMM.		SCHOOL		OTHER		
																										1
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	80

TRACTOR-SEMITRAILER TRUCKS

(3) (4) (5)

3-AXLE SEMI						4-AXLE SEMI								5-AXLE SEMI																		SIX & + AXLE SEMI
STAKE		VAN		OTHER		T	STAKE		R	VAN		CR	O	TANK			STAKE			REF.		VAN			DUMP		GRAIN BOX			CATTLE RACK		
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

(6)

TRUCK-TRAILERS					
HEAVY TRUCK W/TRAILER					
4 AXLE		5 AXLE		6&+ AXLE	
53	54	55	56	57	58

TWIN TRAILERS										
5 AXLE TWIN TRAILERS								6 AXLE TW. TR.		CARD
TANK		VAN		GRAIN B.		OTHER				
										2
59	60	61	62	63	64	65	66	67	68	80

Text Ref.: 5-10.04

July 1,1991	**VEHICLE CLASSIFICATION FORM**	FORM 5.N