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# TRAFFIC DATA COLLECTION, REDUCTION AND DISSEMINATION PROGRAM NEEDS ASSESSMENT

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# 1 INTRODUCTION

Section 1034 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 mandates states to develop a traffic monitoring system. The State of Nevada Department of Transportation (NDOT) had its own traffic monitoring system in place before the act was passed. However, the department has expressed a need to evaluate its current practices to identify areas of improvement.

The Department is currently evaluating its traffic monitoring program based on the procedures recommended by the Federal Highway Administration through its Traffic Monitoring Guide and the standards set by the American Society for Testing and Materials (ASTM) designation E-1442-91 (Standard Practice for Highway-Traffic Monitoring).

## 1.1 Statement of the Problem

Traffic monitoring is defined by the American Society for Testing and Materials (ASTM) designation E-1442 as the "activity of collecting, summarizing and reporting traffic volume, vehicle classification, and vehicle weight data". This comprises of three major elements, namely (Traffic Monitoring Guide, 1985):

1. Continuous count (ATR) element
2. Highway Performance Monitoring System (HPMS coverage) element
    a. HPMS sample subelement
    b. Traffic volume subelement
    c. Vehicle classification subelement
    d. Truck weight subelement
3. Special needs element

NDOT is currently maintaining a traffic monitoring system on its approximately 5,400 miles of road and 3230 count stations. Continuous counts are being performed on its 36 automatic traffic recorders (ATR) which record traffic volume on a continuous hourly basis for a period of one year. Currently, the traffic monitoring year starts from October and ends in September of the following year. Starting 1993, NDOT will perform the annual traffic collection following the calendar year.

The magnitude of data collected annually necessitates an efficient way of managing these data and making them available for use, on a timely basis. The present practice of NDOT is to combine both manual and computerized procedures to facilitate traffic data management.

One of the biggest problems of the Department deals with data management which includes data editing, storage and access, especially when responding to specific requests from the public. The existing traffic system does not provide easily accessible and readable data.

Due to the absence of standardized procedures of traffic monitoring in the past, the Department adopts practices which may or may not be similar with other states and may not be generally acceptable. Manual editing are often performed by the traffic analysts who may follow different procedures of correcting the data. Thus, problems of non-uniformity and inconsistency exist.

The nationwide interest towards standardization of procedures started in 1985 through the issuance of the FHWA Traffic Monitoring Guide. This was followed by the ASTM designation E-1442-91 (Standard Practice for Highway-Traffic Monitoring) and lately, the 1992 AASHTO Guidelines for Traffic Data Programs. The need to evaluate the Department traffic monitoring system becomes more relevant with the development of these standards.

## 1.2 Objectives of the Study

The objectives of this study are to assess the current and future needs of the State of Nevada Department of Transportation and suggest an efficient method of traffic management involving traffic data collection, processing raw traffic data, and a data reporting system.

The Department's goal is to standardize the procedures involve in traffic monitoring and implement full automation of the traffic monitoring system. Prior to the attainment of this goal, the following is performed:

- an evaluation of the Department current practices,
- an identification of areas to be improved or changed, and
- a study of the Department current activities geared towards improving the system.

The NDOT traffic monitoring needs assessment study focuses on three major areas:

- traffic data collection and reduction
- data adjustment/factoring procedures
- information dissemination

## 1.3 Organization of the Report

This study is organized into six major sections which include a description of the state of Nevada Department of Transportation traffic monitoring practices. The topics cover data collection, data adjustment and factoring, and data reporting. Recommendations are given at the end of the report based on the assessed needs of the Department. A descriptive discussion of the NDOT traffic data system is included as a technical appendix.

The following summarizes the major sections covered in the report:

1 Introduction
2 Data collection/reduction
3 Data adjustment/factoring procedures
4 Information dissemination
5 Potential GIS applications
6 Conclusions and recommendations
Technical Appendix - NDOT's traffic data system

# 2 DATA COLLECTION/REDUCTION

The traffic monitoring system is comprised of three elements, namely:

1. Volume counting
2. Vehicle classification
3. Truck weighing

This study deals only with the first two elements: volume counting and vehicle classification. These two elements are within the area of responsibility of the State of Nevada Department of Transportation Traffic Division. The statewide data collection process further grouped as follows:

1. Volume Counts
   a. Continuous traffic counts at permanent Automatic Traffic Recorder (ATR) stations
   b. Short duration counts at designated stations using portable counters

2. Vehicle classification
   a. Short duration counts using manual procedure

A summary of the NDOT's program element is given in Table 2.1.

Table 2.1 NDOT's Traffic Monitoring Program Element

| Element | Sub-element | Count Duration | Number of Counts |
|---|---|---|---|
| Volume Counts | ATR's | 365 days | continuous |
| | Short counts (portables) | 48 hours | 3 times/year |
| Vehicle Classification | Short counts (manual) | 8 hours | 4 times/year |

## 2.1 Volume Counts

### 2.1.1 Continuous traffic counts at permanent ATR stations

Continuous count programs are one of the most prevalent and consistent traffic data collection programs and have become the most basic planning data collection tool in most states. (TMG, 1985). One of the more important functions of continuous traffic counts is the development of seasonal factors to expand short-term counts to annual average daily traffic. Continuous traffic counts are taken 365 days a year on a limited number of permanent stations.

There are 36 permanent Automatic Traffic Recorder (ATR) stations in Nevada. The number and location of these stations were selected randomly. Due to its randomness, it may be worthwhile to check if the sample size adequately represents the Nevada transportation system.

Field ATR data are polled on a weekly basis except in unusual circumstances (such as modem failure or defect in traffic counter) where data can be from 1 hour to 30 days. It may be necessary to monitor field data every day to alert analysts of any equipment malfunctions and count irregularities. This would enable timely detection and correction of problems and potential errors arising from the field. ASTM E 1442 (Section 6.2.4) recommends polling of data at permanent count sites on a 24 hour basis.

Data are normally retrieved via modem to a PC and sent to a mainframe again via modem for statistical analysis. In cases where modem failure occurs, data are retrieved manually. Two types of counters are being used by the Department for continuous traffic counting program. These are the Golden River counters and the Diamond counters. Due to the use of different types of ATR's, data are presented in different formats. Golden River data are produced in ASCII format and presented in a form compatible with the Department program's data input file. Diamond data output in a binary format which necessitate conversion to an ASCII format and re-conversion to Golden River data format prior to analysis. A short conversion program is used to convert data into a format compatible with the NDOT's program. It may be possible to revise the program to enable reading of data presented in various formats, allowing for the use of other, possibly less expensive recorder types.

A Department developed program is used for statistical processing of all field data. This program is menu-driven and was written in COBOL.

Weekly report: ATR data are analyzed weekly to assure quality. From the PC to the main frame, a working copy of the raw traffic data are printed. Appropriate codes are flagged on outliers and data that appear to be questionable or anomalous. The flags include codes that specify estimated data, holiday, storm, special event, data of questionable accuracy, and others. Defective counts are edited prior to acceptance. Corrections are applied manually based on the prior week's (same day) data and/or prior year's data. Data are stored in the mainframe for monthly reporting.

Monthly report: Calculations of average daily traffic (ADT) and expansion factors are performed monthly. Currently, expansion factors are classified into four factoring groups each north and south directions, namely: local, mixed, foreign and recreation. Expansion factors are designated by taking the results of ATR's, grouping them together and taking the representative stations. The traffic division uses Harvard Graphics to plot expansion factors of stations that fall within the same factoring group. Expansion factors are used to calculate the AADT's of segments where only short duration counts were made. Data are stored for calculations of annual average daily traffic. A monthly report is sent to the Federal Highway Administration (FHWA).

The Department is currently reviewing its traffic monitoring program according to TMG standard. This review explores the historical design, procedures, equipment, personnel requirement, and uses of the information.

### 2.1.2 Modifications to existing ATR's

Location of ATR's is being evaluated based on the Traffic Monitoring Guide (TMG) guidelines. Seven stations are planned to be phased out and 27 stations to be added at new locations in 1993. There is also an ongoing review of the factoring groups to check whether the NDOT groupings adequately represent the existing condition. A SAS statistical package was used to perform cluster analysis which would enable clustering of ATR stations with similar characteristics. The previous year's data (1991) was used in cluster analysis. The results enabled re-grouping into nine different pattern groups.

A seasonality peak can be determined for monthly average daily traffic. A flowchart of the continuous count ATR data collection and reduction process is shown in Figure 2.1.

Portable counts or short duration counts are used to estimate vehicle miles travelled (VMT) and provide basic information on traffic volume. For short duration counts, data are collected three times a year at designated stations. There is a plan, however, to reduce the frequency of portable counts to once a year instead of three. ASTM E 1442 (Section 6.1.2.2) specifies that short term mechanical volume measurement shall have a planned duration as follows:

| Type | Duration |
|---|---|
| rural, non-interstate | 48 hours |
| urban, non-interstate | 24 hours |
| rural, urban interstates | 48 hours |
| interchange ramps | 48 hours |
| interstate road segments | 48 hours |

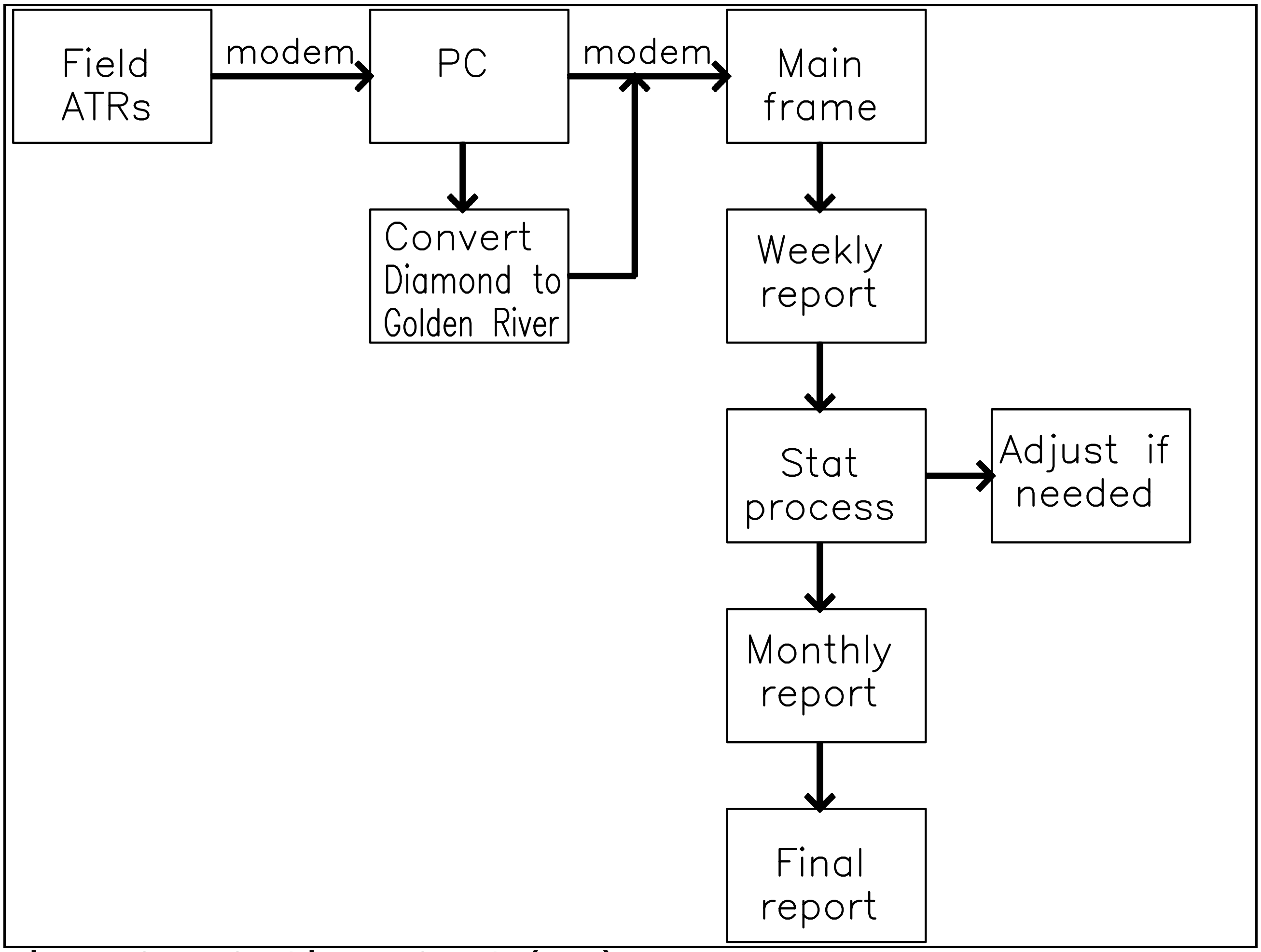



**Figure 2.1 Continous Count (ATR) Process**

### 2.1.3 Portable Counts

If equipment fails with less than 24 hours of data, retake count.

Step

1 Data are colleted 24-hours a day and retrieved weekly via modem.

2 All data are converted into the Golden River format which is in ASCII.

3 Data are stored in a mainframe.

4 Data are analyzed and manually adjusted if necessary.

5 Adjusted data are used to replace bad or missing data.

6 Summary statistics are produced for monthly reports.

7 Annual reports are prepared at the end of the count year and includes summary statistics in directional and composite formats.

Portable counters (e.g. road tubes) are used to collect the data on a continuous seven-day count. These types include Golden River counters, Diamond counters and cumulative counters. The first two counters record counts hourly while the latter provides cumulative totals only. Due to different counters used, the data are presented in different formats which could make data processing time consuming.

Collected data are retrieved manually using a laptop computer before being entered to the mainframe station for AADT calculation. Data are entered manually by a technician who evaluates the data and flags the data if they appear questionable. Once the data have been edited, monthly expansion factors obtained from continuous count ATR stations are used to calculate the monthly average daily traffic (MADT). Monthly expansion factors are not stored on file but are written to hard copy reports. These reports are used by the analyst to obtain the expansion factor that represents the area or station being analyzed. To determine the appropriate expansion factor to use in the calculation of AADT, stations are pre-assigned the factoring group that closely characterize the area. This factoring group was established from the continuous count stations.

An analyst checks calculated AADT manually. If large deviation occurs, the analyst will check the prior year's data or the prior week's data. Adjustment of data will be made based on the analyst's findings. A method of identifying unacceptable data must be formulated. Once formulated, automatic search into the prior years and prior week's data base can be integrated into the system to compare the present data. This will greatly reduce editing time.

If erroneous data are noted, the analyst consults a stack of files from the previous year and the present monthly average daily traffic data are compared. If large discrepancies occur, correction is performed manually. This method can be automated.

Monthly report: NDOT produces a monthly ADT report with information on the station, station grouping used and its respective expansion factor. Additional information includes information on the counter, technician and the dates the short duration counts were performed.

Annual Report: A report showing AADT computations for each station is generated. This report includes the last ten years'

AADT although only the previous year's data is used for comparison to the present AADT. Data are checked manually by an analyst. If the value appears to be questionable, the analyst consults the remarks code to see if any field problems occurred.

Otherwise, he/she would have to consult a stack of files from the previous year, make manual calculation to adjust the value if appropriate. AADT's are manually entered on segments of a network which are in turn used to produce one large copy of a statewide traffic map.

Figure 2.2 illustrates the steps involved in NDOT's portable count program.

The NDOT traffic counting program is a combination of both manual and computerized procedures. An effective system could be designed to automate the entire process. This would greatly reduce the data analysis time and enable the analyst to extract information quickly, also eliminating potential for errors.

## 2.2 Vehicle Classification

Vehicle classification counts are used to estimate axle correction factors and truck percentages. NDOT vehicle classification counts are performed manually four times a year in an eight hour duration. Results of field tube counts are manually entered on the computer, specifying the dates of installation and removal, classification of vehicles and number of vehicles for each classification, and other pertinent information.

ASTM designation E-1442 (Section 6.1.2.1) specifies a minimum of one week vehicle classification data during each quarter over a one year period. The following are ASTM's recommended duration of vehicle classification mechanical measurement:

| Type | Duration |
|---|---|
| rural, non-interstate | 48 hours |
| urban, non-interstate | 24 hours |
| rural, urban interstate | 48 hours |
| interchange ramps (non-isolated) | 48 hours |
| interstate road segments | 48 hours |

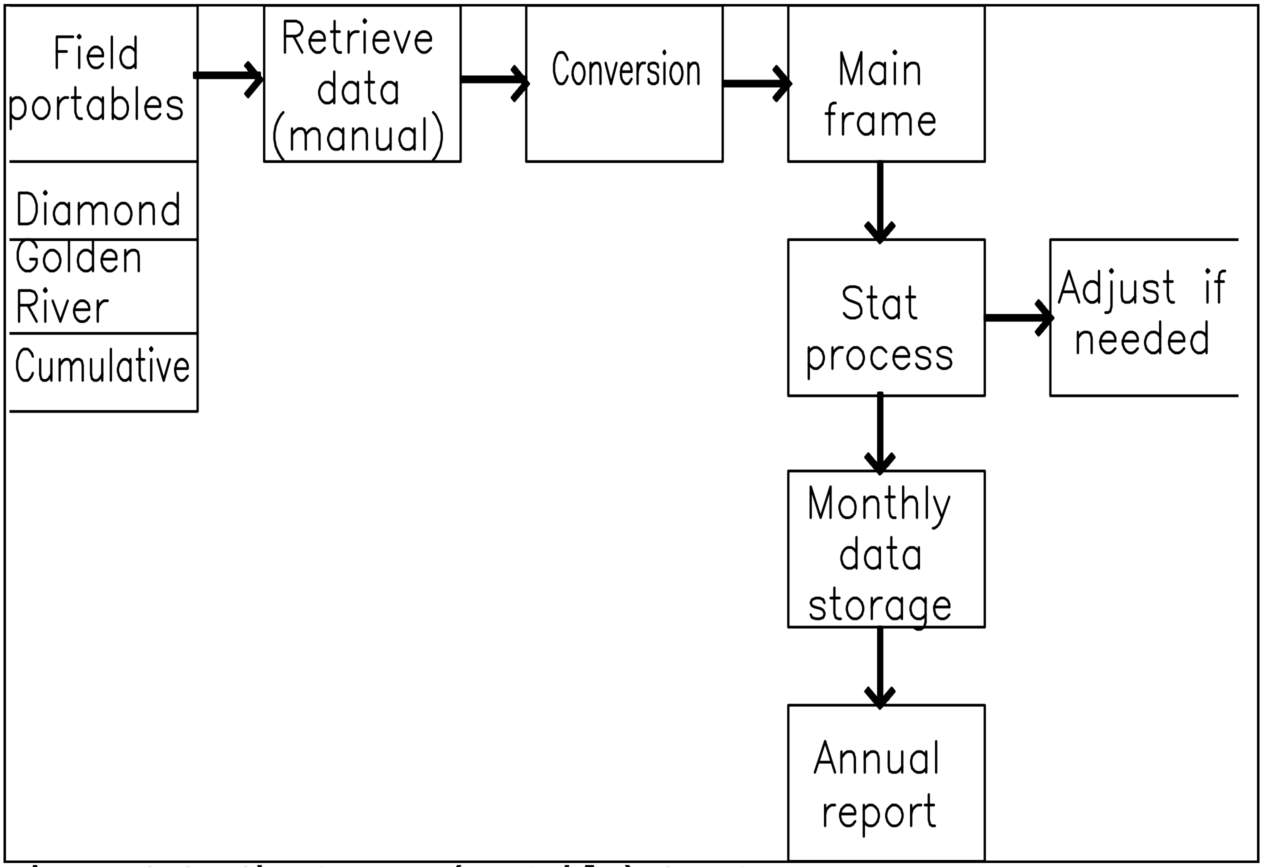



**Figure 2.2  Short Term (Portable) Count Process**

NDOT vehicle classification is comprised of 17 different vehicle types such as shown in Table 2.1:

FHWA classification includes only 13 categories as listed in the Traffic Monitoring Guide.  ASTM specifies mechanical measurement shall be based on the Federal Highway Administration thirteen vehicle classification or if the extra categories are needed for state use, they should be translatable to the FHWA classification.

Step

1   Data are collected three times a year.  Count duration is seven days.  Three different types of counters are used: the Golden River counter, Diamond counter and a cumulative counter.  Raw traffic data are presented in different formats.

2   Data are retrieved daily (?) by field personnel and added manually.

3   A technician enters the data into the mainframe and checks

**Table 2.1 NDOT and FHWA Vehicle Classification System**

| NV Classification | FHWA CLASSIFICATION |
|---|---|
| motorcycles | motorcycles |
| passenger cars | passenger cars |
| pick-ups vehs | other 2-axle, 4-tire S.U. |
| campers | buses |
| 2 axle buses trucks | 2-axle, 6-tire S.U. |
| 3 axle buses trucks | 3-axle, 6-tire S.U. |
| 2 SD trucks | 4 or more axle S.U. |
| 2 SD with camper trucks | 4 or less axle S.T. |
| 3 axle S.T. trucks | 5 axle S.T. trucks |
| 4 axle S.T. trucks | 6 or more axle S.T. trucks |
| 5 axle S.T. trucks | 5 or less axle M.T. trucks |
| 6+ axle S.T. trucks | 6-axle M.T. trucks |
| 5 or less axle M.T. trucks | 7 or more axle M.T. trucks |
| 6 axle M.T. trucks | |
| 7 axle M.T. trucks | |
| 8+ axle M.T. trucks | |

the accuracy of these data.

4 Statistical summary includes monthly ADT. Data are compared to the previous year's and previous week's data. If large deviation occurs, correction is performed manually.

5 Monthly data are stored.

6 Annual report includes a 10-year annual ADT history.copy.

Monthly and annual reports are prepared by the Department. The annual report is an 8-hour summary statistics at observation points. These are not included in the annual traffic report but are maintained in-house. Figure 2.3 illustrates the steps involved in the Department's vehicle classification system.

The Department's vehicle classification program may not be adequate to provide information on seasonal variation in truck travel. This can be used not only for assessing axle correction factors but also for performing accurate pavement design and pavement overlay calculations. It may be necessary to install

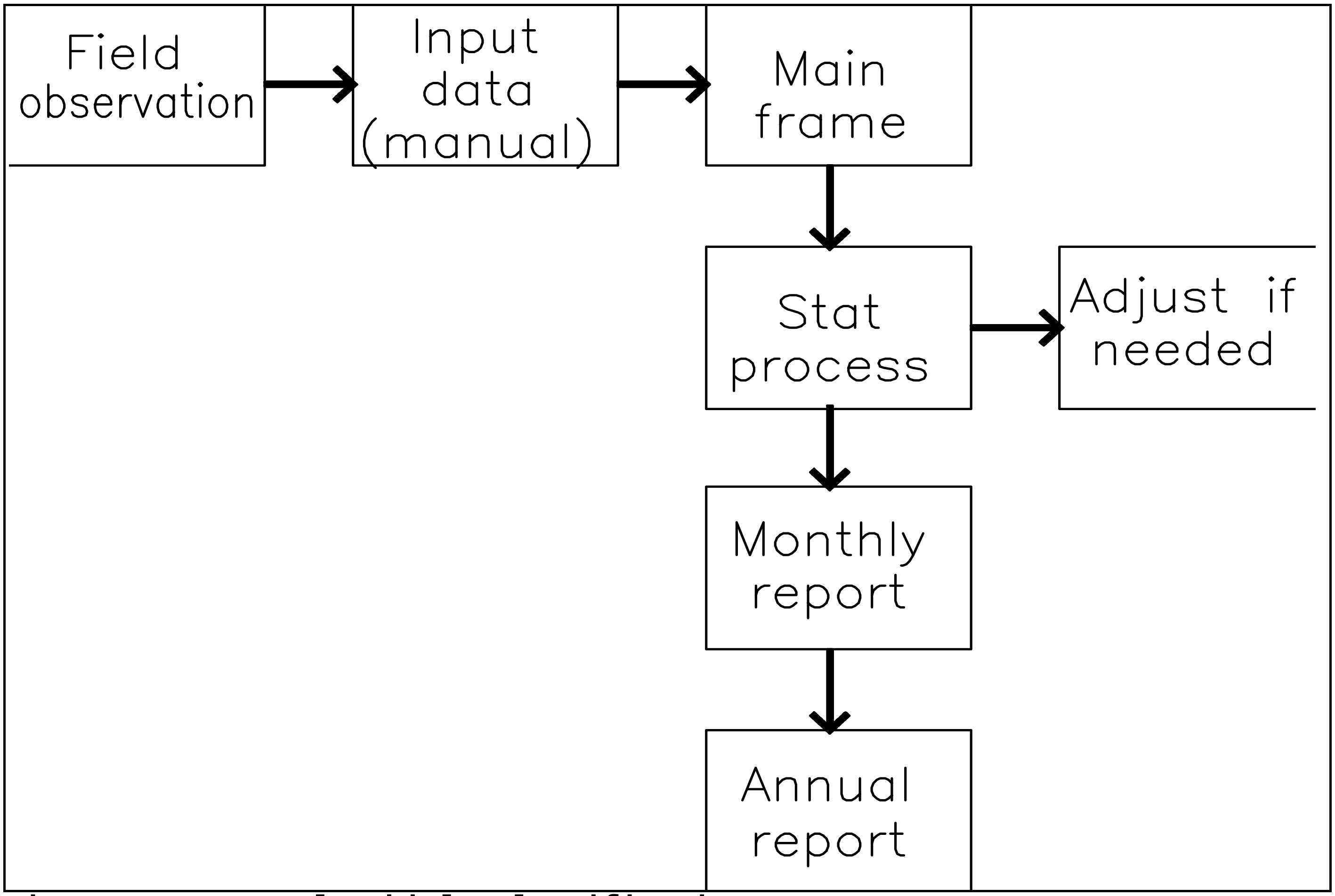



**Figure 2.3  Manual Vehicle Classification Process**

permanent counters to record classification data over a 365-day period. An automatic vehicle classification (AVC) system is planned to be implemented during 1993.

Step

1 Manual vehicle classification is performed by the department's field technicians four times a year for a period of eight hours per observation.

2 Data are entered manually into the computer.

3 An in-house vehicle classification program processes the data and provides summary statistics.

4 Monthly report is produced showing the hourly number of vehicles per category.

5 Annual report is produced showing eight hour statistics.

# 3 DATA ADJUSTMENT/FACTORING PROCEDURES

Data adjustment or editing is an important aspect of a traffic monitoring program. Editing is performed "to ensure that field measurements are valid prior to being summarized and reported." (AASHTO, 1992). In this study, an assessment of the Department's data adjustment/factoring needs is comprised of two general areas:

1) Define the requirements for digital traffic data processing following the Traffic Monitoring Guide and ASTM standards.

2) Review NDOT procedure for data reduction/correction (i.e., methods used to calculate expansion factors, AADT and VMT).

One of the goals of standardization, aside from ensuring uniformity of data collection and editing practice, is full automation of the traffic data monitoring system. The Department does not have this capability yet, especially in terms of automating data adjustment and factoring. The following discussions identify areas which have potential for automation.

## 3.1 Data retrieval

*Raw data*. As mentioned previously, three methods of data retrieval are being used by NDOT. Each method depends on the type of counting device used. Permanent count data are retrieved electronically via modem. These data are polled on a weekly basis. Portable count data are retrieved manually by field technicians using laptops or manual recording. For manual vehicle classification raw data are obtained manually during the observation.

To facilitate data polling, the permanent automatic traffic recorders could be connected to office computers and retrieved on a 24-hour basis as recommended by ASTM E-1442. A 24-hour data retrieval is more preferable than the weekly data retrieval practiced by the Department because this would enable timely detection and correction of field problems such as equipment malfunctions and count irregularities.

For vehicle classification, the Department plans to use automatic vehicle classification which would replace manual vehicle classification.

*Data format conversion*. The computerized traffic system reads input data with the Golden River counters data format. Use of a different type of counter will produce a different data format.

Since NDOT also uses diamond counters a conversion program was developed to convert diamond data to the Golden River data format. Both the Golden Rivers and Diamond counters provide adequate data, especially for hourly analysis, however, cumulative counters produce only the total accumulated value from the period the counter was installed to the period the count was recorded. This type of counters is not recommended for traffic monitoring except if hourly data will be recorded. When manually done will, this will not be practicable at all.

*Data entry* (portable and manual counts). Three types of portable counters are currently being used by NDOT. These are the Golden River counters, Diamond counters and cumulative counters.

Erroneous data are substituted by values extrapolated from the prior year's data. Similarly, extrapolated data are used in lieu of anomalous data which the analyst determines to need adjustment.

Both ASTM and AASHTO stress the principle "TRUTH IN DATA". This emphasizes the need to keep the data as close to reality as possible where "missing or inaccurate unedited base data shall not be completed, filled-in or replaced". As noted, the NDOT practice is to fill-in missing data or replace bad data by extrapolating from the prior year's or prior week's data. The program is structured in such a way that permanent counts shall be based on 365 days, or 366 for leap year, with no flexibility to exclude days with bad data.

Outliers, or those data counted during special events (on-going construction), are to be included for permanent counts but not for short duration counts.

### 3.2 Data editing

*Permanent counts (ATR)*. The Department's method of checking the acceptability of hourly data is based on a fixed percentage of comparable data which could be the previous hour's data, next hour's data, and same hour of last week's data. The following statistical checks are used:

Hourly edit checks

Ratio A = (hour being checked)/(previous hour, this week)
Ratio B = (next hour, this week)/(hour being checked)
Ratio C = (hour being checked)/(same hour, last week)

where

Ratio A < 1.4 and > 0.8
Ratio A < 0.8 and Ratio B < 1.2

Ratio A < 0.8 and Ratio B > 1.2 and Ratio C > 0.8 and < 1.2
Ratio A > 1.4 and Ratio B > 0.8

If any of the above conditions is not satisfied then the data are considered questionable.

Another condition is set as follows:

THIS > HIGH or THIS < LOW then data is questionable

where

THIS = the hour being checked
HIGH = AVG + RANGE
LOW = AVG - RANGE
AVG = the average for the same hour for every weekday
RANGE = (0.0842 * AVG) + 31.58

While the edit conditions provide reasonable assessment of the validity of the data, additional edit checks are necessary. If possible, edits based on a fixed percentage of comparable data should be avoided. While standard techniques of editing data are not yet well defined, some edit provisions are given in ASTM designation E-1442. Some of the recommendations specified in ASTM designation E-1442 (Sections 7-2.4 to 7-2.5) can be assimilated within NDOT's system:

1) If the daily directional total volume is within 60 to 80 percent of total traffic, issue a warning.
2) If the daily directional total volume exceeds 80 percent, do not include in calculation.
3) If the daily traffic volume for a given day of week differs ±2 standard deviations from the mean volume for that day in the month, treat it as an outlier. Recalculate mean volume excluding the outlier. Variability may be assessed based on the current year monthly average day of week (MADW), prior year MADW, the three year average MADW or any combination of the three.

These three edit provisions can be automated.

*Portable counts*. AADT estimation using short duration counts is a complex problem. (TMG, 1985). Ideally, measurements should be taken on every section of the road. However, this process is cost prohibitive.

The standard procedure for estimating AADT from portables is by use of adjustment factors. Factors include temporal or seasonal factors (estimated from ATR samples), day of week and axle correction factors, and growth factor.

For portable counts, manual editing is comprised of manually checking the traffic data from hard copy report. A print file is generated with calculations of AADT's extrapolated from the short duration observations using expansion factor. From the hard copy report, an analyst checks the values of the traffic data manually. The analyst usually judges whether the data is acceptable or not. If unacceptable data are noted, the analyst will trace the reason for the anomaly, and adjust the data where appropriate. Data adjustment consists of three or four different methods. The most common method is referencing the prior year's data or prior week's data. For counts taken with a tube, an axle correction factor is used to recalculate AADT using manual method (that is finding the applicable factor and multiplying by the AADT using manual calculation).

Edited data are entered back into the computer manually. If one is dealing with thousands of stations, the process becomes highly routine, straining and possibly, error prone.

Editing of portable data can be automated and integrated within the system, with provisions for tube counts or axle corrections. The calculated AADT can thus be reported in final form, saved to disk and printed.

*Vehicle classification*.

The Department is planning to adopt the automatic vehicle classification system (AVCS) for the 1993 calendar year. This system will facilitate electronic collection and transfer of vehicle data, which will further reduce the usefulness of the manual classification program.

## 3.3 Adjustment Factors

Generally, the final annual average daily traffic is estimated as follows:

where:

$AADT_f$ = final AADT
ExpFactor = seasonal or expansion factor
AxleFactor = axle correction factor
ADT = average daily traffic

### 3.3.1 Expansion factors

Expansion or seasonal factors are used to account for seasonal variations in traffic condition and are used to expand AADT's from short duration counts. These factors are calculated automatically using the Department's computer program for traffic data analysis. The results are printed in paper but are not stored on file.

*Factoring Group*

Group factors are derived for each of the factoring group. The latter is determined by plotting the expansion factors using Harvard Graphics (R) software. Stations that display the same characteristics are manually grouped together under one factoring group. The final choice of the stations representing one factoring group are often made by the traffic analyst. This practice may suffer from inconsistency, especially if more than one analyst perform the selection.

Eight factoring groups are currently being used by the Department, namely: north local, north foreign, north mixed, north recreational, south local, south foreign, south mixed, and south recreational.

Recently, nine new factoring groups are being considered by the Department. These groups were determined from cluster analysis using 1991 data. These are the northern rural interstate, northern urban interstate, other northern rural, northern recreational, other northern commute, central rural, southern rural interstate, southern urban interstate, other southern rural.

TMG recommends at least 5 to 8 locations per factoring group. This represents reliability levels of "10 percent precision with 95 percent confidence for each seasonal group..." as recommended by TMG. The groupfactors are used to evaluate portable or short duration traffic data.

To establish factoring groups, it may be necessary to develop trends analysis using historical data from the existing ATR stations. This will help identify and group together stations that display consistent and similar characteristics.

*Group Expansion Factor*

The following identifies the Department's procedures for determining the group expansion factors to calculate AADT from portable data. These procedures are built within the system:

1. Determine the pre-assigned factoring group for the portable station.
2. Search through the ATR files to find the stations that belong to the said factoring group and determine the traffic volume.
3. Repeat step 2 until all stations within the same factoring group are identified.
4. Add the volumes of all identified stations.

5. Calculate the expansion factor.
6. Multiply the expansion factor in Step 5 by the traffic volume to obtain the AADT at one portable station.
7. Move to the next portable station and repeat the procedure starting from step 1.

As noted, the procedure only pre-assigns a factoring group for each station. The group expansion factors for each factoring group are not calculated and retained on file for immediate access during succeeding calculations. Instead, the group expansion factors are calculated for each station, regardless of whether the group expansion factor representing the factoring group of the said station has already been previously calculated. Data storage requires space which could be utilized for storage of large traffic data (those utilizing 15 minute count, especially at the ATR's permanent stations). However, re-running the program may prove more costly due to the computer time spent on evaluating something that has already been analyzed previously.
The following suggestion may require less computational time:

1. Determine the pre-assigned factoring group for the portable station.
2. Search through the ATR files to find the stations that belong to the said factoring group and determine the traffic volume.
3. Repeat step 2 until all stations within the same factoring group are identified.
4. Add the volumes of all identified stations.
5. Calculate the group expansion factor.
6. Assign the estimated group expansion factor for each factoring group
7. Multiply the group expansion factor in Step 6 by the traffic volume to obtain the AADT at the portable station.

### 3.3.2 Axle correction factor

Axle correction factor is applied to convert short duration volume counts to AADT only when these counts are obtained using a tube dectector, or an equipment that records the number of axles instead of the number of vehicles. With the future phasing out of tube detectors, these factors will no longer be used.

The axle correction factor is manually applied to the seasonally expanded AADT to determine the final AADT. In case the axle corrected traffic volume shows large deviation from other counts, the correction factor is manually adjusted by the analyst using his judgment and upon consultation from the prior year's data.

## 3.4 Data storage

Continuous and short duration count data should be permanently stored and compiled in a readable format.  A short program could be written to do this.  At present, there is no efficient way of accessing traffic data except through hard copy reports.

The Department currently retains a 10-year historical record of summary statistics from portable count stations.  ASTM recommends that "The calculated summary statistics from traffic measurements shall be permanently maintained by the agency calculating the summary statistic..."

Vehicle classification data should also be stored permanently.

## 3.5 Traffic System

The Department has developed a traffic system for statistical processing of traffic data.  This consists of computer programs which are written in COBOL.  These programs are categorized into 2 groups, Station Master and Count History.  A more descriptive evaluation of the system is contained in the Technical Appendix.

Due to the absence of standardized procedures of traffic monitoring in the past, the Department adopts practices which may or may not be similar with other states and may not be generally acceptable.  With the issuance of ASTM designation E 1442-91, AASHTO Traffic Guidelines and TMG, a re-evaluation of the existing NDOT traffic data collection, data processing and information dissemination has become necessary.  One objective is to integrate the provisions of these guidelines or standards into the existing programs.

### 3.5.1 Strengths and weaknesses of the existing system

The existing system aids the Department in the editing and summarization of data and preparation of tabular reports.  Without the system, the time required to process and finalize all the data will be much longer.

The existing system is currently being upgraded in the Department's Data Processing Division.  However, large amounts of time and effort would be required to implement all changes.  These changes would include revision of data structure to make it more user-friendly, some provisions of TMG, ASTM, and AASHTO, and some editing works such as calculation of AADT using axle correction factors.  A new system may need to be developed or purchased or the existing system may be revised to implement all the changes.

While the system facilitates data management, potential areas of improvement have been identified.  These are listed as follows:

1. Data are stored in a packed decimal format which make them very difficult to retrieve and interpret.

2. The system does not allow quick retrieval of data for analysis or to provide quick response to users requests.

3. The system does not have the flexibility to skip days with bad counts or missing data due to equipment malfunction.

4. For portable counts, the system does not allow calculation or input of axle factor and final adjustments of annual average daily traffic data. Expansion factors for portable count data are not stored and have to be recalculated everytime.

5. AADT data from portable counts are not stored which necessitate manual re-entry of final (corrected) AADT.

6. The system does not provide adequate documentation.

7. The system includes many variables that are not used at all, which tend to convolute the system.

8. The system includes some features which are already outdated due to the addition of new traffic counters and due to some changes in the traffic counting program.

9. The system does not identify real and estimated data.

10. The system does not provide automatic editing options, especially for portables and permanent counts.

# 4 INFORMATION DISSEMINATION

## 4.1 Identification of users and use of the annual traffic report

Traffic reports are produced for a wide variety of applications which range from statistical compilation of records to applications in engineering, planning and economic analysis. Some of the specific uses of the NDOT traffic reports are for public information dissemination, for Federal Highway Administration (FHWA) reporting, and for answering specific requests by the public, consultants, and engineers. Internally, the report is being applied to planning, design, cost allocation, and other uses.

Direct users of the NDOT annual traffic reports include the Federal Highway Administration; NDOT planners, designers, economists and engineers; local governments and private consultants. Traffic data for FHWA are transferred electronically while data for other users are transferred in paper format.

Some examples of studies making use of traffic characteristic data are summarized in Table 4.1.

## 4.2 Department Data Reporting System

As mentioned in the previous section, three types of reports are generated by the Department traffic division: the weekly report, monthly report and annual report. These reports are maintained in the NDOT files and can be accessed by interested users anytime. Annual reports and AADT monthly reports are distributed for public use.

*Weekly report*. Weekly reports are generated for the permanent count stations or ATR's. These reports are maintained in-house.

*Monthly report*. Monthly reports are generated for all aspects of the traffic monitoring system, namely: continuous counts, portable counts and vehicle classification.

*Annual traffic report*. At the end of the one year count period, a final report is prepared showing the annual average daily traffic (AADT), vehicle-miles travelled, and other data. These reports are presented in tabular form.

The Department's annual report is segregated into five main parts which include the following:

<u>Documentation</u>
data collection, statistical calculation

Table 4.1. Examples of Studies Making Use of Traffic Characteristic Data

| Highway Management Phase | Traffic Counting | Vehicle Classification |
|---|---|---|
| Engineering | Highway Geometry | Pavement Design |
| Engineering Economy | Benefit of Highway Improvements | Cost of Vehicle Operation |
| Finance | Estimates of Road Revenue | Highway Cost Allocation |
| Legislation | Selection of State Highway Routes | Speed Limits |
| Planning | Location and Design of Highway Systems | Forecasts of Travel by Vehicle Type |
| Research | Methods of Improving Highway Usage Efficiency | Traffic Simulation |
| Safety | Design of Traffic Control Systems | Safety Conflicts Due to Vehicle Mix |
| Statistics | Average Daily Traffic | Travel by Vehicle Type |
| Private Sector | Location of Service Areas | Marketing Keyed to Particular Vehicle Types |

Source: FHWA Traffic Monitoring Guide, 1985.

<u>Automatic Recorder Counts</u>
AADT
Percent of preceding year
Percent 30th highest hour volume is of annual average
Monthly ADT
Ten-year historical ADT record at ATR

<u>Primary State Highway System</u>

Cumulative miles
AADT
Average truck ADT
Annual VMT
Truck annual VMT

<u>Annual Traffic Portable Recorder Stations</u>

10-year AADT

*Traffic map*. In the past, the annual report contained traffic maps with AADT data. This map was produced using a camera-ready, hand-drawn base map of Nevada which was maintained in the division. A transparent sheet was overlaid in this map where AADT's were transferred by using numbers manually pasted on the transparent sheet. This practice was both time and labor intensive.

In 1991, the department did not publish the AADT map but instead published only the maps which show the location of ATRs and portable stations. The annual traffic report contains maps which show the following:

Location of fixed count stations
Highway base map
Traffic counting station map

Currently, the Department has computer-generated maps of all stations and intersections segregated by county. This is expected to be included in future traffic reports.

Manual production of maps is time consuming and maybe prone to error. This also does not allow flexibility in making some changes such as deleting a link that has been closed for traffic, re-distributing a district and a wide variety of applications without having to reconstruct the whole map. While map production was and can still be done manually, a Geographic Information System (GIS) can be used to automate this process. This would not only reduce the time spent in map production, but would also allow graphical presentation of various traffic data. Graphical data are easier to visualize and manipulate. The ability to access a large database in a short period of time makes it a very useful analytical tool in transportation engineering. If the database are already complete, county (or other jurisdictional) traffic maps can be generated.

*Requests for Specific Traffic Data*. The Department has been receiving numerous requests for hourly traffic distribution data, which are currently not included in the Annual Traffic Report. Other requests involve finding historical data on one particular day (say, Memorial day) or event. These requests could not be readily provided because the program's data structure makes access to the data very difficult. Normally, the Department facilitate these requests by manually pulling out data from reports.

A short program could be developed to facilitate specific requests but only if the edited data are stored in an easily readable format.

## 4.3 Current Practices of Other State Department of Transportation

The present NDOT annual traffic report was compared with those of California's, Oregon's and Utah's.

Table 4.2. Report Formats of Other States

| State | Annual traffic report | Report format |
|---|---|---|
| California | PHV; peak MADT; AADT | tabular data; highway map |
| Oregon | AADT; color coded range of AADT's | traffic volume map |
| Utah | begin MP-end MP; 3-yr AADT; ATR's: MADW; MAWDT; % ave day is of ave weekday; % monthly daily ave is of annual daily ave | tabular data; ATR stations and AADT map |
| Nevada | AADT; % of previous year's AADT; % 30th highest hour is of annual ave; MADT; 10-yr historical record | tabular data; ATR stations map |

Note: AADT - annual average daily traffic; MADT - monthly average daily traffic; PHV - peak hourly volume; MADW - monthly average days of the week; MAWDT - monthly average weekday traffic; MP - milepost

It can be noted that AADT is the most common traffic data reported and is most commonly used. Data are commonly reported in book (tabular data) and map form (graphical data).

A desired system should have the flexibility to provide data that would respond to a wide variety of needs: VMT's, traffic volumes, vehicle classification and others which may not necessarily be contained in one voluminous report. In addition to AADT and VMT, some traffic data which may provide useful information are daily hourly volume (DHV), peak hour percentage (K), directional design hourly volume (DDHV), peak hour volume (PHV) and 30th highest hour volume (HV).

## 4.4 Improving the Quality of Disseminated Information

In general, information should be presented in a way that is easily understandable to the user. This should be precise, readable and should contain useful information. Traffic data are numerical data which can be presented effectively through tables, graphs, and maps. Tables are the most common forms of presenting large amount of data because they are easy to prepare. Graphs are very useful in presenting temporal variations of traffic data, such as the monthly average daily traffic. They could also facilitate selection of the 30th highest hourly volume. Maps could show the spatial distribution of various traffic attributes in relation to the traffic network.

In the final report, the type and form of data to be reported should be based on the following considerations:

- the identified users of the traffic data
- the type of information required by the users
- the purpose of the traffic data
- the length of time required to produce the data

# 5 POTENTIAL GIS APPLICATIONS

The Geographic Information System can be used as a tool for traffic monitoring system. Potential applications are in the field of traffic data editing, data storage and data reporting as indicated in Figure 5.1. Traffic data can be combined with other spatial data such as population, emissions and landuse to perform various types of analysis such as safety, air quality, and impacts of new developments.

## 5.1 Data Collection

For the Department's data collection program, GIS can be used to facilitate the following activities:

1) Random selection of count locations

GIS can be used to select count locations for new counting programs or identify additional new locations or locations that have to be abandoned because they no longer represent the needs of the traffic counting agency.

This can be done by overlaying the transportation network on a land use coverage. When assigning locations based on functional road classification, the functional road classification data can be overlaid on the transportation network to distribute the locations uniformly.

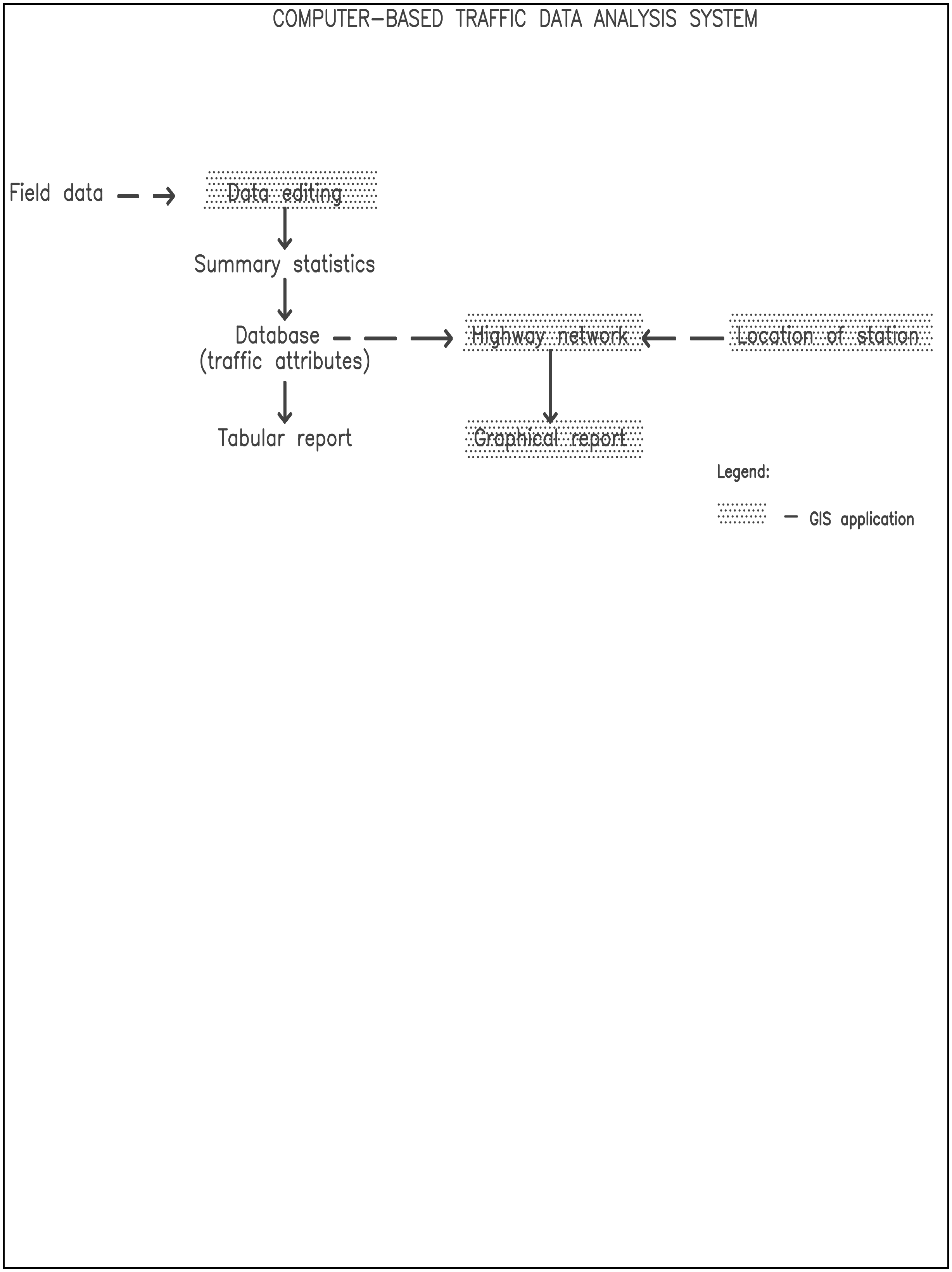
2) Location of stations for permanent counts (ATR) and short-term counts (portable)

Locations of permanent count stations, portable count stations, vehicle classification count stations and others can be displayed in a road network.

## 5.2 Data Editing

1) Traffic count data

GIS can be used to edit spatial traffic count data. The count data could be overlayed on a road map. If there is a questionable count or largely deviating count data, this could easily be noticed by an analyst. Multiple counts could be displayed to compare the questionable count to some other counts taken on the same roadway and the same time period. If an inconsistency is found and no explanations can be given to it, the questionable data can be excluded from the analysis.


COMPUTER-BASED TRAFFIC DATA ANALYSIS SYSTEM
Field data
Data editing
Summary statistics
Database
(traffic attributes)
Highway network
Location of station
Tabular report
Graphical report
Legend:
— GIS application

In the absence of a count on the same roadway and the same time, the prior year's or prior week's data could be displayed to analyze how the station with questionable count compare with other stations. If the same trend is observed, the count can be accepted. Otherwise, if it is different and no explanations can be attributed to it, then the count could be excluded but maintained for other pourdoses sucha as research.

2) For spatial data such as annual average daily traffic, "automate spatial traffic editing within the GIS." (AASHTO, 1192, pp. 36)

### 5.3 Data Storage

1) Historical traffic data can be stored within a GIS framework.

Traffic data derived from a traffic monitoring system can be exported to and stored in GIS.

Trends analysis can be readily performed using historical traffic data. Specific needs, such as traffic information along one road segment on Thanksgiving day for the last ten years, can be readily pulled out from a GIS file.

### 5.4 Data Reporting

The Geographic Information System can greatly facilitate presentations of traffic data. Its superior graphics capability can provide quality maps which can be very useful to the analyst and other users of all traffic data.

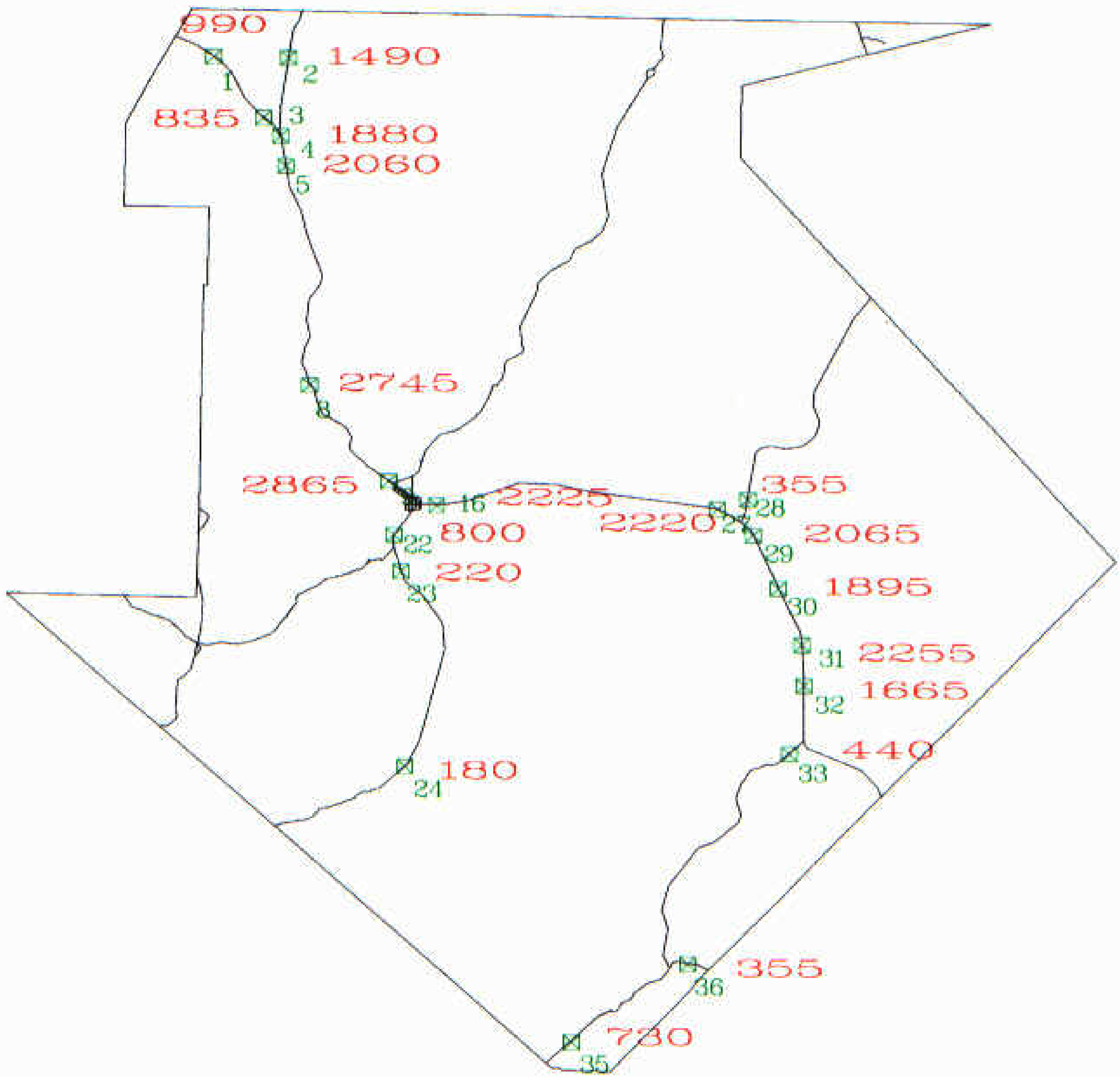
A map showing the location of various count stations can easily be produced using GIS. These stations can be segregated by county, district or state, depending on the need of the Department and the expressed need of the users.

A traffic map containing AADT or Peak hour traffic volume can be generated using GIS. Again, the map can be segregated by county, district or state, depending on the need of the Department. The station map can be overlayed with the traffic map for a more comprehensive graphic presentation.

Similarly, a map showing the VMT distribution along the road network can be produced. When combined with other spatial attributes, this can be used for evaluating the VMT's implication to air quality, road serviceability and fuel consumption.

# 1991 AVERAGE DAILY TRAFFIC COUNTS

## MINERAL COUNTY HIGHWAY SYSTEM

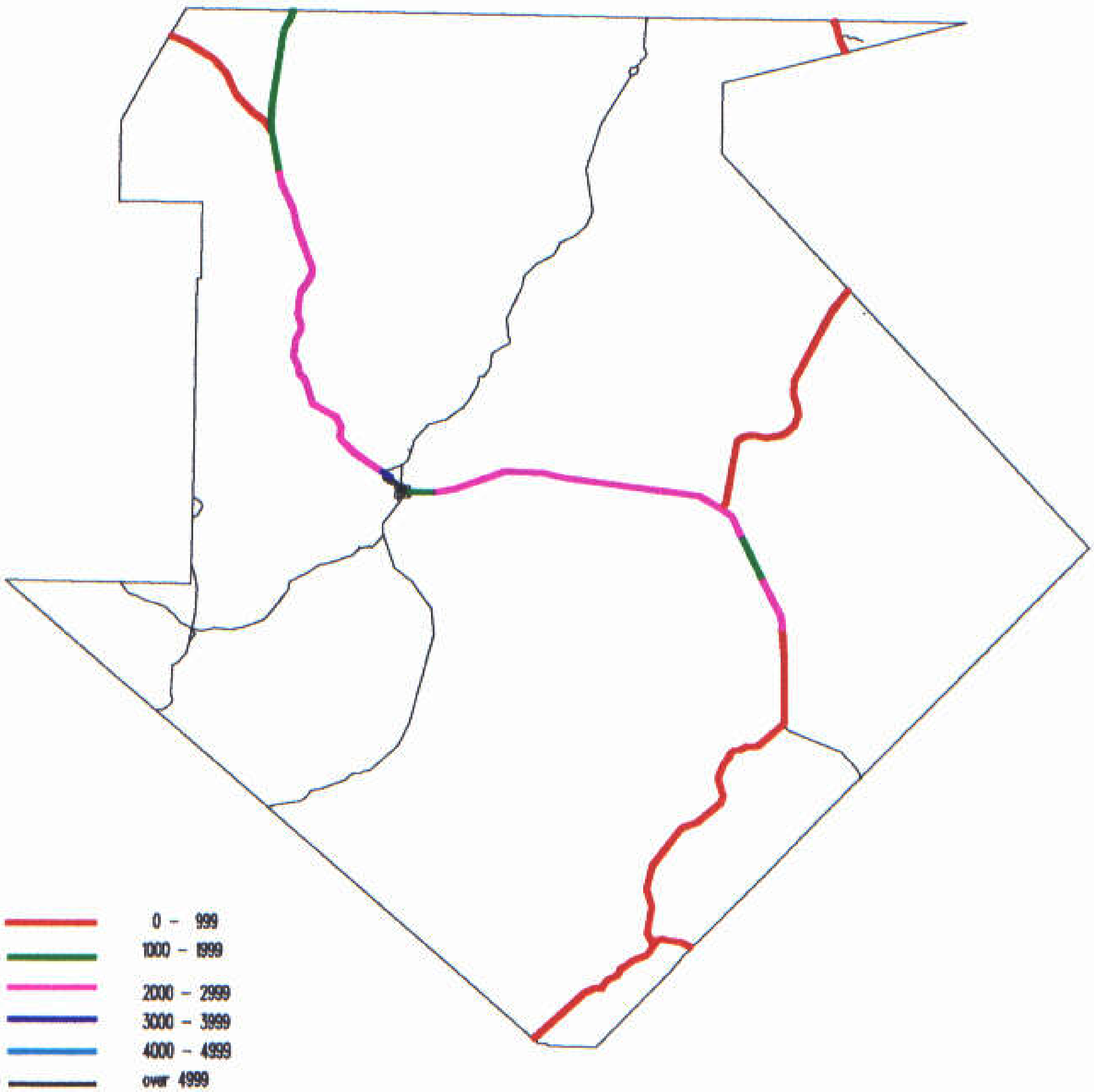



excludes Hawthorne – Babbitt city limits

# 1991 TRAFFIC FLOW MAP

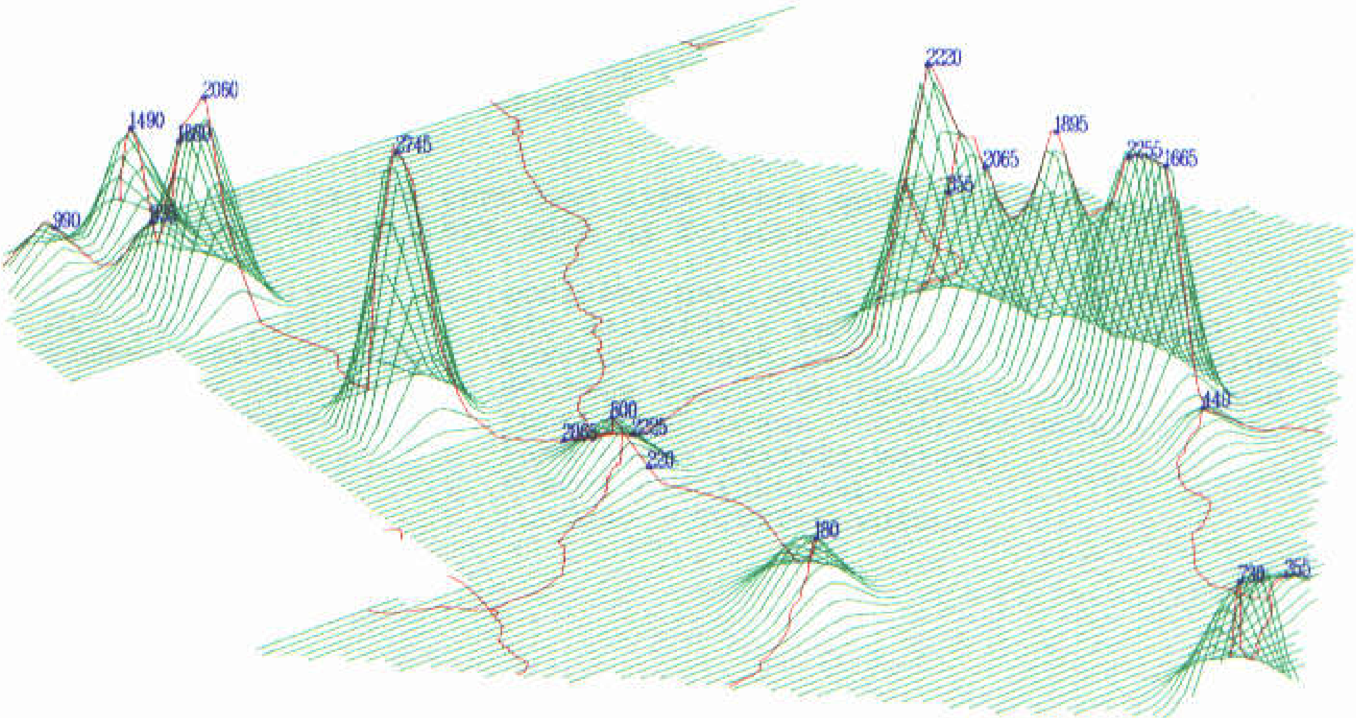
## MINERAL COUNTY HIGHWAY SYSTEM

VOLUMES SHOWN ARE ALL VEHICLE ANNUAL AVERAGE DAILY TRAFFIC



# AVERAGE DAILY TRAFFIC COUNTS

## MINERAL COUNTY




excludes Hawthorne-Babbitt city limits

There are several methods by which traffic data can be presented within the GIS framework. Station data can be presented numerically at their locations as illustrated in Figure 5.2. This method is the traditional and the most common method of presenting traffic data graphically. As previously noted, NDOT used to publish this type of map using manual method. Color codes can be used to represent data ranges at different road segments. With color coding, the least busy to busiest road segments can readily be identified as shown in Figure 5.3. Figure 5.4 illustrates a new method of presenting traffic data using three dimensional plots. This method will be most effective when performing an analysis which combines traffic data with other attributes. An example is safety analysis. In Figure 5.5, traffic data is combined with accident data to show how traffic volume affects the magnitude of traffic related accidents. This will provide an analyst a quick assessment of variables affecting safety which can then serve as the basis of his/her succeeding decisions or program of actions.

## 5.5 Other applications

1) Several types of analysis can be performed by combining traffic data with other spatial and non-spatial data.

Based on the identified use of the traffic data, specific examples showing some potential applications of GIS is given in Table 5.1.

Traffic data can be combined with other spatial data to arrive at other types of analysis such as follows:

| | | |
|---|---|---|
| Accident Analysis | : | accident data file + traffic volume |
| Air Quality Study | : | air emission + vehicle miles traveled |
| Highway Maintenance (priority ranking) | : | surface condition rating + traffic volume<br>surface condition rating + vehicle class |
| Highway Improvement | : | functional class + traffic volume |
| Planning | : | land use + traffic volume + mode distribution |
| Impacts of New Development | : | landuse + traffic volume |

Table 5.1 Examples of GIS Applications Making Use of Traffic Characteristic Data

| Highway Management Phase | Traffic Count | Vehicle Classification |
|---|---|---|
| Engineering | vol vs. lane dist | % veh dist |
| Engineering Economy | traffic distr | % veh dist, % location of toll |
| Finance | veh miles traveled | veh distribution |
| Legislation | vol vs. road classn | veh class vs. functl class |
| Planning | vol vs land use/demographic | vol vs. veh distr vs. land use |
| Research | vol vs acc vs road type | comm veh distr vs major facilities - IVHS |
| Safety | vol vs acc rate<br>VMT vs emission for air quality | veh distr vs acc per veh type |
| Statistics | traffic map, VMT dist | veh distr |
| Private Sector | vol vs landuse vs population | % comml veh vs loc of facilities for routing and scheduling delivery |

# 6 CONCLUSIONS AND RECOMMENDATIONS

The traffic monitoring system comprises of three different areas:

- volume counting
- vehicle classification
- truck weighing

This study addresses only the volume counting and vehicle classification programs of the State of Nevada Department of Transportation, Traffic Division. Volume counting includes both continuous or ATR counts and short duration or portable counts.

The State of Nevada Department of Transportation traffic monitoring system is characterized by a semi-automated process. Continuous counts are retrieved automatically from the field to the office prsonal computer via modem and processed using the computerized traffic system. Portable counts are retrieved manually from the field and processed using a semi-computerized method. Vehicle classification are performed manually. While the existing traffic system facilitates data processing, several things can be done to improve the system especially in the areas of data polling, data editing and preparation of final report for public dissemination.

The long term goal of the Department is directed towards standardization and complete automation of the traffic monitoring system. Prior to the attainment of this goal, the following is performed:

- an evaluation of the Department current practices,
- an identification of areas to be improved or changed, and
- a study of the Department current activities geared towards improving the system.

Due to the absence of standardized procedures of traffic monitoring in the past, the Department adopts practices which may or may not be similar with other states and may not be generally acceptable. Manual editing are often performed by the traffic analysts who may follow different procedures of correcting the data. Thus, problems of non-uniformity and inconsistency exist.

The nationwide interest towards standardization of procedures started in 1985 through the issuance of the FHWA Traffic Monitoring Guide. This was followed by the ASTM designation E-1442-91 (Standard Practice for Highway-Traffic Monitoring) and lately, the 1992 AASHTO Guidelines for Traffic Data Programs.

The need to evaluate the Department traffic monitoring system becomes more relevant with the development of these standards.

The NDOT traffic monitoring needs assessment study focuses on three major areas:

- traffic data collection
- data factoring/adjustment procedures
- information dissemination

Data collection

Much of the improvements in data collection are being undertaken by the Department in accordance with TMG, ASTM and AASHTO standards. Some of these are to be implemented in the 1993 calendar year.

Permanent traffic data are electronically transmitted from the site to the main office but other data are polled manually. With the installation of the automatic vehicle classification system in 1993, only the portable traffic data will remain to be polled manually.

Data factoring/adjustments

For permanent counts, the Department's current practice involves plugging-in missing or bad count data using extrapolation from the previous counts. A program alerts the analyst of questionable data, which will enable him to decide whether to accept the data, or reject and substitute it with extrapolated data.

Correction factors

The seasonal or expansion factor and the axle correction factor are the two factors being applied to calculate the annual average daily traffic (AADT). Currently, these factors are applied manually. Axle correction factors are entered after appropriate expansion factors have been applied in the traffic volumes for stations counted with tube detectors.

The main difficulty with the assignment of expansion factors is in determining the stations that represent each factoring group. Each year, the stations are grouped based on the results of expansion factors calculated from the permanent stations. Stations showing similar monthly trends and similar values are grouped together and fitted under one factoring group. Group expansion factors are used for portable counts AADT estimation.

Information dissemination

Traffic reports are processed monthly and annually for public distribution. The existing system does not have the capability of computerized production of graphic reports. Currently, however, count stations at county level are being digitized for inclusion in the next Annual Traffic Report. The capability to store and read data and subsequently produce maps can be developed within the Geographic Information System and integrated in a new or upgraded traffic system.

NDOT traffic data system

Based from the results of the needs assessment study, the following are recommended:

1 Data collection

1. Continue evaluation of the NDOT data collection program based on acceptable standards such as TMG, AASHTO and ASTM.
2. Sample size for each type of data collection program should be statistically valid.
3. For permanent counts, it may be necessary to monitor field data on a 24 hour basis instead of a weekly basis. This would enable timely detection and correction of problems and potential errors arising from the field.
4. For permanent count program, determine the seasonal or factor group base on conditions that correctly represent the area. Ensure that each factor group has adequate sample size. TMG recommends that the sample reliability levels be of "10 percent precision with 95 percent confidence for each individual seasonal group...". This translates to at least 5 to 8 samples for each factor group. The factoring group should be determined from cluster analysis using historical data (more than one year data) to establish consistent trend.
5. To facilitate data polling, the automatic traffic recorders could be connected to office computers. For vehicle classification, the Department plans to use automatic vehicle classification which would replace manual vehicle classification.
6. For spatial data such as annual average daily traffic, "automate spatial traffic editing within the GIS" (AASHTO, 1192, pp. 36).

## 2 Data factoring/adjustment procedures

The following are recommended to facilitate data factoring and adjustments:

1. Both ASTM and AASHTO stress the principle "TRUTH IN DATA". This emphasizes the need to keep the data as close to reality as possible where "missing or inaccurate unedited base data shall not be completed, filled-in or replaced". "Imputation" or the process of estimating missing or edit rejected data should be avoided. (AASHTO, 1992, pp. 37, ASTM, 1991).
2. Adopt generally accepted standards or procedures for data factoring and adjustments. These procedures should be well documented and included in the traffic data system.
3. Develop a standardized procedure for estimating correction factors.
4. Use statistically valid data based on standard deviations instead of fixed percentages. Edits based on a fixed percentage of comparable data should be avoided. While standard techniques of editing data are not well defined, some edit provisions are given in ASTM designation E-1442. Some of the recommendations specified in ASTM designation E-1442 include the following:

    1) If the daily directional total volume is within 60 to 80 percent of total traffic for that day, issue a warning.
    2) If the daily directional total volume exceeds 80 percent of the total traffic for that day, do not include in calculation.
    3) If the daily traffic volume for a given day of week differs ±2 standard deviations from the mean volume for that day in the month, treat it as an outlier. Recalculate mean volume excluding the outlier. Variability may be assessed based on the current year monthly average day of week (MADW), prior year MADW, the three year average MADW or any combination of the three.
5. Short duration traffic data which do not represent typical traffic should not be

included in the calculation of annual summary statistics. Examples include data taken during a holiday, and while there is an ongoing construction, (AASHTO, 1992, pp. 32). For permanent counters, atypical data should be included. (AASHTO. 1992, pp.33).

## 3 Information dissemination

To produce quality tabular and graphical reports and still minimize production time, the following are recommended:

1. Automate graphic reports within the Geographic Information System or other computerized system.
2. For a new or upgraded system, provide for the creation of an export file for GIS.

## 4 Traffic data system

In general, the NDOT traffic monitoring program can be greatly improved with the development or acquisition of a fully automated traffic data analysis system. This could be attained by any one of the three alternatives:

1. Upgrade NDOT's existing system to reflect current developments, improve data storage, exclude irrelevant information and provide user flexibility.

2. Develop a new traffic data analysis system that will satisfy the Department current and future needs and reflect current developments which aim to standardize traffic monitoring practices such as those in AASHTO, ASTM, and TMG.

3. Purchase a commercially developed system that will cater to the present needs of NDOT's traffic monitoring system.

The advantages and disadvantages of each of the three alternatives are discussed in Technical Appendix A and are summarized below:

Alternative 1 *Upgrade the existing system*

- would require very careful review of the programs to identify areas that need to be added/improve to conform with standards (AASHTO, ASTM or TMG)
- understanding the program flow may be difficult and time

consuming
- reformatting data structure may necessitate changing a major portion of the program, which can become more complex than writing a new one
- analyst and programmer can work together to ensure that NDOT needs are adequately represented

Alternative 2 *Develop a new system*

- can be designed to respond to the needs of NDOT traffic monitoring program
- system can be designed to conform with standards such as AASHTO, ASTM or TMG
- can be more flexible
- needs a proficient programmer
- the operating platform has to be carefully selected due to the large-capacity storage requirement of traffic monitoring
- may not be readily available
- will require additional time to test and validate

Alternative 3 *Purchase a commercially available system*

- readily available
- less time spent in data handling/management
- shorter time required to produce traffic reports
- may require training to learn the system
- highly dependent on the system developer
- user cannot change conditions that are already built into the system
- may not adequately meet the needs of the Department
- may be cost-prohibitive

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# TECHNICAL APPENDIX

## NDOT's TRAFFIC DATA SYSTEM

The Nevada Department of Transportation has an existing traffic data system which allows partial automation of traffic monitoring process. The system is menu driven. It highlights four section menus, namely: option, data entry, run request and log. The option menu allows selection of the type of system to be used. This includes seven different types, each having a unique function. Data entry enables creation of data files such as count data, off-system data and others. For every option, run request enables data conversion, editing and updating of data, and monthly and annual data processing. A log of completed runs can be made using the log option.

Without this system, data processing will be manually exhaustive. In addition, the time required to manually process the data will be much longer. While the system facilitates data analyses and summarization, much can be improved to achieve full automation and to integrate current technological and legislative developments. At present, the system undergoes regular modifications or trouble-shooting by staffers who are familiar with the workings of the program.

The Department's traffic system was developed long before the ASTM and AASHTO standards were published and thus may suffer from lack of standard procedures for data factoring and adjustment. The adjustment processes are left to the judgement of the analyst who is also relegated the responsibility of checking and manually correcting questionable data.

### Existing traffic system description

The Department's traffic system is menu driven and comprises of several program modules, namely: common system, fixed system, portable system, vehicle classification system, off-system, manual system, and warrants. Each module is characterized by a unique function as shown in Figure A-1.

Some of the disadvantages of the existing system have been identified as follows:

1. Data are stored in a packed decimal format which make them very difficult to retrieve and interpret.
2. The system does not allow quick retrieval of data for analysis or to provide quick response to users requests.
3. The system does not have the flexibility to skip days with bad counts or missing data due to equipment malfunction.
4. For portable counts, the system does not allow calculation or

input of axle factor and final adjustments of annual average daily traffic data. Expansion factors for portable count data are not stored and have to be recalculated every time.

5. AADT data from portable counts are not stored which necessitate manual re-entry of final (corrected) AADT.
6. The system does not provide adequate documentation.
7. The system includes many variables that are not used at all.
8. The system includes some features which are already outdated due to the addition of new traffic counters and due to some changes in the traffic counting program.
9. The system does not identify real and estimated data.

**System Alternatives**

An evaluation of the existing system revealed a need for a new system (whether purchased or developed) or upgrading of the existing system. This need is based on the following factors:

1. the identified weaknesses of the existing traffic system
2. the current changes in the Department's traffic counting program
3. the standardization of the traffic monitoring practice
4. the desire for full system automation

Three alternatives are addressed to satisfy this need. These are as follows:

1. Upgrade the existing system
2. Develop a new system
3. Purchase a commercially available system

*Upgrade the existing system*

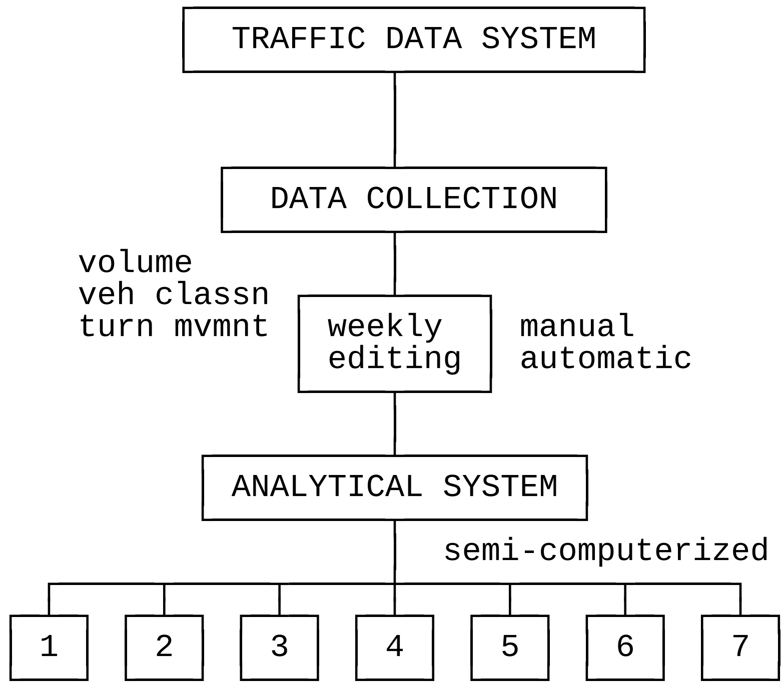
The existing system comprises of different program modules to facilitate data editing and summarization. (See Figure ). While the system utilizes computers, some elements are not integrated in the system and have to be performed manually. Examples of which include manual data entry of portable and manual traffic counters, editing of the final AADT, and production of non-tabular reports. Significant time savings will be gained if the current system is improved.

If the system will be upgraded, the decision-maker may be faced with the following questions:

1. How much will it cost to upgrade the existing system?

2. How long will it take to upgrade the existing system and implement it?
3. Does the Department have the resources to upgrade the system?

Existing System




1 Common system. Edits and lists Golden Rivers data.
2 Fixed system. Processes continuous counts at ATR's.
3 Portable system. Generates VMT's, 10-year historical ADT's, MADT's, AADT's.
4 Vehicle classification system. Edits manual counts and produces vehicle classification reprot based on 23 vehicle categories.
5 Off-system. Generates AADT outsided the Department's regularly maintainesd stations.
6 Manual system. Edits manual count transactions and produces listing of errors.
7 Warrants. Analyses count data from a four-way intersection turn movement study and produces warrants.

Figure A-1. Existing traffic system description

*Develop a new system*

A new system can be designed to reflect the Department's current and future needs such as shown in Figure A-2. The system can integrate some programming language with GIS to facilitate data storage, summarization and reporting, and minimize manual input.

However, if a new system is developed, the decision-maker could be faced with the following questions:

1. How much will it cost to develop a new system?
2. How long will it take before the new system becomes operational?
3. Under what operating conditions will the system be designed?
4. Does the Department have the resources to develop a new system?

New System

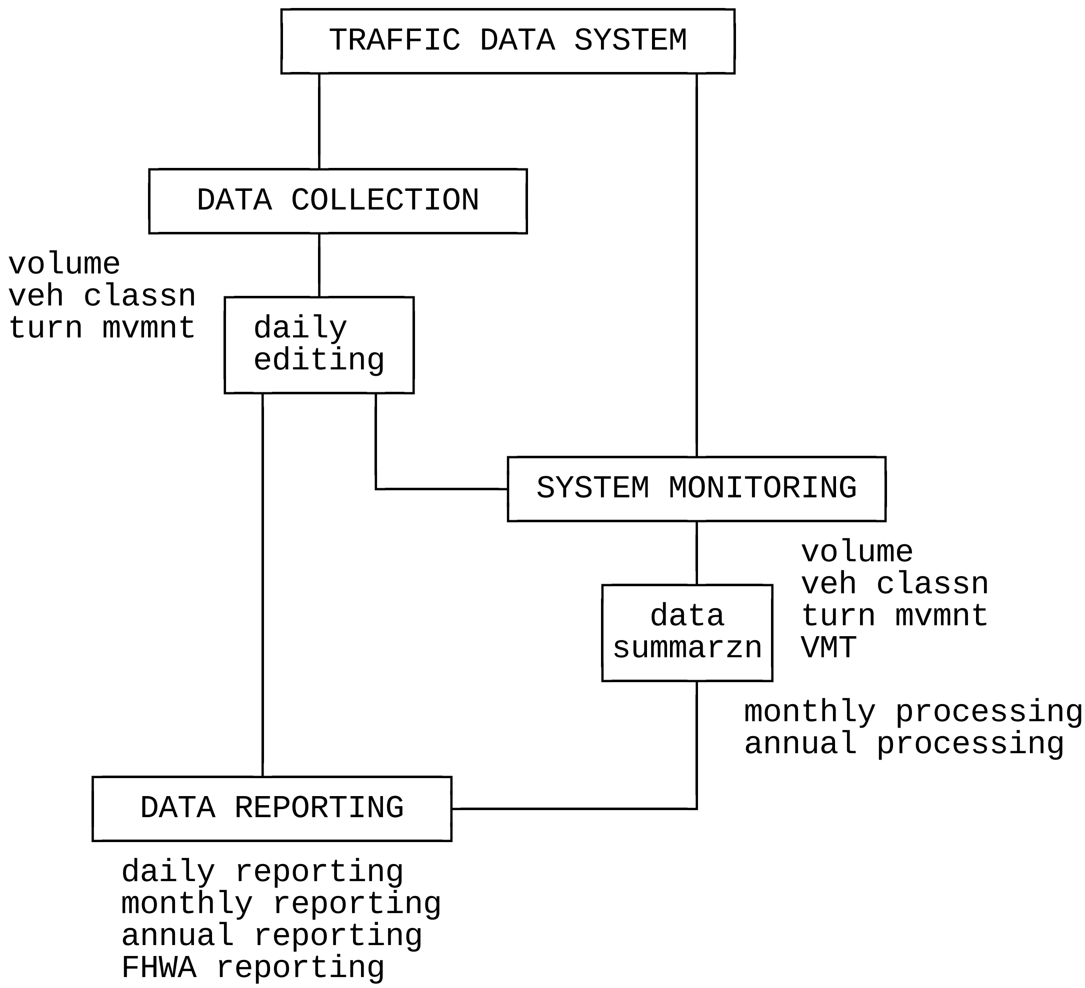



Figure A-2. New traffic data system description

*Purchase a commercially available system*

An integrated traffic data collection and analysis system or TRADAS (traffic data system) is commercially available. It consists of two subsystems: the Data Collection Management System (DCMS) and the Standard Traffic Monitoring System (STMS) shown in Figure A-3. The former is a data polling system while the latter performs data editing, analysis, and reporting. The system integrates the provisions of ASTM E-1442, Standard Practice for Highway Traffic Monitoring, AASHTO's Guidelines for Traffic Data Programs, FHWA's Traffic Monitoring Guide, and Highway Performance Management System (HPMS). Some of the interesting features of the system are its ability to display graphical outputs such as daily average VMT's monthly variation and annual variations in monthly average daily traffic; and ability to create district and municipal traffic map data export files for CADD or GIS.

The cost of installing the system, however, appears to be very high. The basic STMS package alone would cost $150,000.000. The DCMS package is $25,000.00.

If the purchase of a new system is being considered, the decision-maker should examine the following questions:

1. What softwares are available in the market?
2. How much will be the total cost of installing and maintaining the purchased system?
3. What are the requirements for installing and using the system (i.e., user training, hardware requirement, computer memory requirement, processing time)?
4. How long will it take to install and implement the purchased system?
5. Does the system adequately meet the Department's needs?

TRADAS
(Commercially Available System)

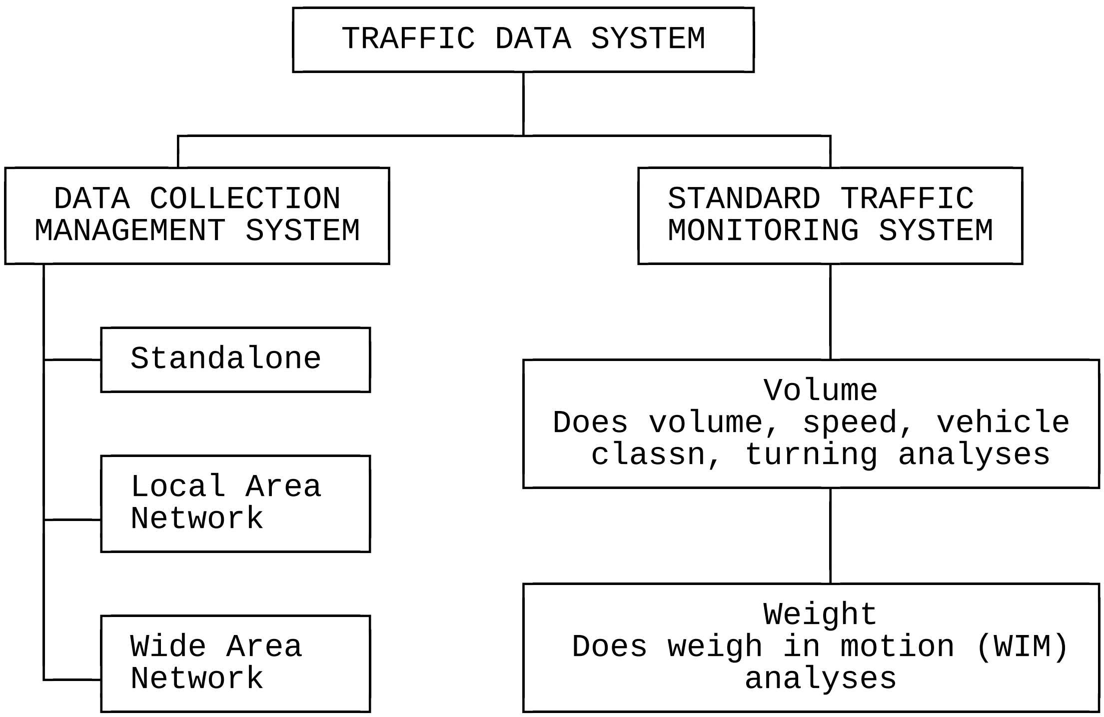



Figure A-3. TRADAS product description and options
(Source: The TRADAS Product Description, CSC 1992)

The following summarizes the advantages/disadvantages of each of the three alternatives:

Alternative 1 *Upgrade the existing system*

- would require very careful review of the programs to identify areas that need to be added/improve to conform with standards (AASHTO, ASTM or TMG)
- understanding the program flow may be difficult and time consuming
- reformatting data structure may necessitate changing a major portion of the program, which can become more complex than writing a new one
- analyst and programmer can work together to ensure that NDOT needs are adequately represented

Alternative 2 *Develop a new system*

- can be designed to respond to the needs of NDOT traffic monitoring program
- system can be designed to conform with standards such as AASHTO, ASTM or TMG
- can be more flexible
- needs a proficient programmer
- the operating platform has to be carefully selected due to the large-capacity storage requirement of traffic monitoring
- may not be readily available
- will require additional time to test and validate

Alternative 3 *Purchase a commercially available system*

- readily available
- less time spent in data handling/management
- shorter time required to produce traffic reports
- may require training to learn the system
- highly dependent on the system developer
- user cannot change conditions that are already built into the system
- may not adequately meet the needs of the Department
- may be cost-prohibitive

Comparison of Alternatives

The following lists down some of the existing system weaknesses and how a new or upgraded system can be used to address each of these weaknesses:

**Data are stored in a packed decimal format which make them very difficult to retrieve and interpret.**

In Cobol programming, data can be stored using a COMP-3 option. This option is usually selected to save storage space by packing numerical data. When data is packed, it can not be read for printing because each byte does not contain a zone and digit as in normal coding.

Apparently, storage space was a concern for NDOT when these programs were written because they all contain the COMP-3 option. Unfortunately, this only contributes to the difficulty of retrieving, analyzing and interpreting the count data. There are other programs and programming languages available today which can compress data in a more efficient and simplified manner without losing the ability to retrieve and manipulate the data easily.

* It may be possible to write a program (SAS-based, or other) that will decipher the variable each cell or group of cells represents and store it in a readable format.

+ A new traffic data analysis system can be developed using a different programming language which can compress data and still maintain their integrity.

**The system does not allow quick retrieval of data for analysis or to provide quick response to users requests.**

Because the numerical data are not normally coded, data cannot be retrieved quickly.

* With the creation of a new data file, this problem will be eliminated.

+ A new system can include feature which will allow the user to retrieve data on a a specific location and specific time period. Otherwise, the stored data can be linked to a GIS file such that a location can just be zoomed in and its attributes can be wasily displayed.

**The system does not have the flexibility to skip days with bad counts or missing data due to equipment malfunction.**

The programs are not equipped to skip days with bad or missing count data. A separate program has been written (PTRFC010) to correct this problem by inserting estimated data in place of the problem data. The questionable days are defined by the user - there does not appear to be any automated method of finding and flagging the bad data.

* ASTM and AASHTO specifications emphasize the principle "truth-in-data" and avoidance of data replacement or imputation. Major revisions may be needed if these standards are to be followed.

+ A new system can have the capability to disregard days with "bad or unacceptable" counts and base traffic estimates on the actual number of observation days.

**For portable counts, the system does not allow calculation or input of axle factor and final adjustments of annual average daily traffic data. Expansion factors for portable count data are not stored and have to be recalculated everytime.**

The axle factor and the AADT are defined variables within the Station Master File - Portable. As the portable counter programs are currently written, they can not be changed or adjusted. However, a program (PTRPC040) calculates a monthly ADT from the portable counts and produces a printed report. The monthly ADT is calculated as: Month ADT/Month EXP FACT/Days in Month.

* A new variable can be added to the program to facilitate entry of axle factor which could in turn be used to calculate final AADT. The axle correction factor equals one for counts taken with loop detectors. The monthly ADT can then be estimated as Month ADT/Month EXP FACT * AXLE FACT/Days in Month.

+ A new system can provide individual cells for expansion and axle correction factors which could be used to estimate the AADT.

**AADT data from portable counts are not stored which necessitate manual re-entry of final (corrected) AADT.**

The monthly ADT factors are not permanently stored when they are calculated in program PTRPC040. But the Station Master File - Portable does contain a stored ADT and expansion factor. It is not clear where these values are calculated. Expansion factors are also stored in the Portable-Transaction-File, but it is not clear where or how they are calculated.

* Once the axle factors for tube counts are integrated into the system, an additional command could be included to store the final AADT on a data file.

+ This problem is not likely to be encountered in a new system.

**The system does not provide adequate documentation.**

One recurring problem with almost all of the programs reviewed (both fixed and portable) was that they lacked clear, descriptive comment statements to help follow the program flow. This is particularly important if the programs are to be kept in the COBOL programming language. Because of COBOL's limited usage, it is imperative that adequate documentation be added so that a programmer of another computer language can follow the program flow easily.

* Inadequate documentation prevents the user from understanding the full capability of the program as well as from checking the validity of the equations used to calculate traffic data. The entire programs can be

reviewed, with careful attention to the codes used and documentation added to the system.

+ In a new system, each part of the program can be adequately explained and documented during its development stage.

**The system includes many variables that are not used at all.**

COBOL requires every field of an input or output file to be defined. Some of the files defined in these programs are very lengthy and have numerous fields which are never used. One example is the expansion factor in the fixed counter programs. It was defined over and over again, but it was never utilized. This was typical of many of the variables defined from the input files. This implies that the input files may (if not used for other reasons) be storing more information than is actually needed, or storing information that is not being utilized to provide more accurate count data.

* The program should be precise and concise. A review of the system will be needed to identify and subsequently eliminate all unnecessary variables.

+ With a new system, the program flow can be carefully designed to ensure that only the necessary variables are included in the system.

**The system includes some features which are already outdated due to the addition of new traffic counters and due to some changes in the traffic counting program.**

The system contains numerous information that have become irrelevant such as employee data (field technician), and data conversion for counters that were no longer used. Because of this, the programs have to be revised on a regular basis. This does not only delay the analysis but also consume manhours which could have been allocated to some other work.

* Although some portions of the system are outdated, with som modifications they can provide the same information that a newer, packaged software program could provide. The difference is more of a storage and usage issue. A new packaged program would be much more user friendly and probably use much less storage space.

Changes that are currently being implemented by the traffic division (such as the use of automatic vehicle classification, and the use of other traffic counters) would render some parts of the system unusable.

+ With the development of a new system, outdated features will naturally be eliminated. The developed program can be reviewed regularly to ensure that new developments or changes within the department are reflected on time.

**The system does not identify real and estimated data.**

Real data are mixed with estimated data that it is very difficult to identify one from the other.

+ This problem will be minimized irrelevant if ASTM and AASHTO standards are followed which discourage the practice of data imputation. A line could be added to the existing programs to detect and automatically flag estimated data.

* A new system can be designed to skip days with bad or erroneous counts.

Note:
* - proposed revised system
+ - proposed new system

**Selection factors**

From the above discussions, the selection process can be based on five diffeent factors which can be factored into time, manpower expertise, hardware requirement, costs, and system flexibility.

1. Time. The time required to revise the existing system or develop and validate a new system before it becomes truly operational should be considered in the selection process. For the commercially available system, the time required to purchase, install and familiarize the user with the newly purchased system should be considered.

2. Expertise. The level of expertise of the programmer should be taken into consideration when deliberating on developing a new system or rewriting the existing one.

3. Hardware requirement. The current system resides on a Motorola station. When developing a new system, the work station and the memory required to maintain a historical database should be considered.

4. Costs. Costs cover direct and indirect costs. The cost of revising the system or developing a new one, and the cost of maintaining the system should be considered in the decision process.

5. Flexibility. A new program can be designed based on the Department's present and projected needs. For the existing system, it may be difficult to redesign the system in accordance with the needs of the Department and still maintain a certain flexibility. The system user and program developer should work together to ensure that the Department needs are adequately represented.