Development of State Traffic Monitoring Standards: Implementing *Traffic Monitoring Guide* in New Mexico

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A study of traffic monitoring practices was undertaken by the New Mexico State Highway and Transportation Department. The study reviewed current practice in relation to the *Traffic Monitoring Guide*, published by the FHWA. The study concluded that state traffic data requirements could best be met, and the *Traffic Monitoring Guide* could best be implemented, by developing statewide traffic monitoring standards. Standards were drafted, refined, and adopted. All traffic data are required to be in conformity with the state standards. The immediate benefit is standardization of traffic data. Data are equivalent and directly comparable, enhancing project selection and design. This process establishes the basis for testing and evaluating traffic monitoring statistics and procedures.

A study of traffic monitoring practices was undertaken by the New Mexico State Highway and Transportation Department. The study reviewed data collection, summarization, and analysis practices. Practices were reviewed within the department, among metropolitan planning agencies and other governmental units in New Mexico, and departments of transportation nationally. The study was conducted in response to concerns for state data integrity, and in relation to implementation of procedures recommended in the *Traffic Monitoring Guide*, published by the FHWA in 1985 (*1*).

METHODOLOGY

A study design was drafted, reviewed, and adopted. The study methodology included review of literature, interviews concerning current traffic monitoring practices in New Mexico, interviews concerning current traffic monitoring practices nationally, drafting state traffic monitoring standards, and standards implementation and evaluation.

The study began with a comprehensive review of traffic monitoring literature. Through this review, the *Traffic Monitoring Guide* was identified as providing the basis for improving the accuracy and efficiency of traffic monitoring.

After the review of literature, interviews were conducted with all departmental personnel involved in traffic monitoring. A series of three separate interviews was conducted with each individual. The interviews addressed operational procedures, statistical methods, and current and potential computerization of work. Current practices among the three state metropolitan planning organizations were also reviewed.

On the completion of the in-state interviews, all state departments of transportation were surveyed. Two separate telephone surveys were conducted. One survey concerned statistical methods used in traffic monitoring. The second identified computerization of traffic monitoring among the state departments.

On the basis of the literature review, interviews, and surveys, a process was proposed to develop state traffic monitoring standards. Standards were drafted through a consultative process and were refined through state and federal review. After formal adoption, training was provided to implement the state standards.

The final element of the study design was to maintain the state standards as an open-ended process. An annual review and refinement of the standards was established, as well as verification of standard compliance.

NEED FOR STATE TRAFFIC MONITORING STANDARDS

The traffic monitoring study determined that the current traffic monitoring practices in New Mexico produced questionable traffic monitoring data. Most practices resulted in data for which a confidence level and interval could be calculated neither on a system- nor site-specific level.

A primary source of error in traffic monitoring was inconsistent use of professional judgment in factoring traffic data. Professional judgment was applied to adjust base data and complete missing data. The judgment of professionals resulted in multiple modifications of the same data set. Traffic counts were modified up to eight separate times by individuals unaware of previous or subsequent modifications. These judgments were made during field collection, data summarization, selection and application of adjustment factors, and data use. The adjustments modified the initial data in conflicting ways. In most instances existing practice prevented identification of original base data after modifications had been made.

The study also identified inconsistency in data-collection procedures. Among agencies in New Mexico, and within some

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agencies, the length of count and use of adjustment factors varied substantially. All traffic volume data were typically labeled average daily traffic (ADT). This resulted, for example, in a traffic-flow map with average weekday traffic on some roads and average 7-day week traffic on other roads all being labeled as ADT. Some same-map traffic volumes were mixed data, including average annual daily traffic (AADT) from permanent traffic recording devices, 24-hour unadjusted count data, 48-hour count data with axle correction and seasonal adjustment factor, and non–count-based estimates. All volumes were labeled ADT and presented as equivalent data. Of more concern, all data were analyzed as equivalent data in highway project simulation, selection, and design.

The error in professional judgment must be assessed in relation to data use. One use of traffic volume data is for assessment of alternative routes for urban areas. Nonequivalent data, as described above, were used in a gravity-model computer simulation of Taos, New Mexico. From these data a bypass was indicated. Equivalent traffic data as potentially (and eventually) required under state standards were then collected, and one-way street changes were indicated rather than a bypass.

Review of the department's highway project selection process indicated the dominant role of traffic volume. Potential projects with similar roadway distress were being selected on the basis of ADT. Comparison of highway projects in the project selection process will be enhanced, and some selected projects will change, as traffic data are equivalent.

Similar changes have been calculated in relation to pavement design. Pavement thickness was determined by the department as sensitive to differences in traffic-volume data summarization. Inaccurate current-year data typically establish future trends that, when forecast to design year, result in under-building or over-building a facility (*2*). Improving current-year traffic volume data as required under the state standards typically resulted in a design change of one-half in. in pavement thickness.

Improvement in vehicle classification data will have additional design impact. Rural Interstate data from then current vehicle classification practices were compared with data collected as potentially specified under state standards. Under then current practice there was a characteristic underestimate of heavy commercial vehicles by 6 percent in the total traffic volume data.

In network simulation, highway planning, project selection, and pavement design, traffic data practices were inadequate to data use. The problem with individual practices is accentuated when comparing data from various locations and from various sources. Data consistency is an issue nationally. No state surveyed was found to have adopted statewide standards for traffic summary statistics. No models were available from other states for such standards. Practices then common in New Mexico were typical of other states. This would suggest that national traffic data bases contain nonequivalent data. Future efforts at national traffic data bases should examine base data through specified collection procedures, summarization techniques, adjustment factors, and factor sources applied to the base data.

At every governmental level in New Mexico, the study determined that traffic monitoring summary statistics were inadequately reported. Proper understanding and use of these data would require definition of the summary statistic and method. Except for cursory descriptions of count factors and methods, information was unavailable that would allow summary statistics to be appropriately used. There was a critical need for adequate reporting procedures in transmittal of traffic monitoring summaries.

As a result of the study, it was concluded that the traffic monitoring practice within the department must be redesigned. It was also concluded that the improvement should be statewide and required for all public and private traffic monitoring practices related to state and federally funded road projects. This would provide the opportunity for the department to compare data, to avoid mixed data, to avoid politically inspired data (traffic data collected in a manner to show a desired conclusion) in the state data base, and to use these data appropriately in transportation planning and engineering.

PROCESS OF DEFINING AND IMPLEMENTING THE STATE STANDARDS

Nine traffic monitoring technicians in New Mexico were invited to participate in drafting state traffic monitoring standards. The department, each metropolitan planning organization, and other interested agencies were represented. Copies of traffic monitoring technical documents were distributed to the participants. Preliminary discussions of traffic monitoring issues were conducted. All participants were then gathered for an intensive 2-day period. The traffic monitoring standards were drafted through this consultation.

The procedure used during the consultation was based on specific types of traffic data. Each type of data (or data element) was addressed, from collection through summarization and analysis. After data elements were defined, discussion proceeded on what practices should be followed. Although data elements were considered individually, the principle of nesting was adhered to, as defined in the *Traffic Monitoring Guide*. The intention was to help ensure the most efficient use of collection activities. After the consultants had reached consensus on separate data element standards, an overall review was conducted. This resulted in simplification of the proposed standards, and a final draft was adopted by the participants.

The draft standards were reviewed and refined at the state and federal level. Final standards were prepared and adopted under departmental administrative memorandum. The memorandum was signed in May, 1988, and the standards went into effect October 1, 1988. This allowed a period of standards training before implementation. The standards are required for all traffic monitoring data on any road in New Mexico for which state or federal moneys are used or are proposed to be used.

OVERVIEW OF THE STATE TRAFFIC MONITORING STANDARDS

The New Mexico state traffic monitoring standards contain 89 separate specifications for traffic data collection, summarization, and analysis. The structure of the state standards follows that of the *Traffic Monitoring Guide* (*1*). The stan-

dards begin with characteristics required of all traffic monitoring in New Mexico and then detail practices required by type of monitoring: automatic traffic recorders, coverage counts, vehicle classification counts, weigh-in-motion (WIM) counts, manual counts, and other concerns such as monitoring equipment.

In the early stages of the New Mexico study it was decided that any modifications to current practice should implement the *Traffic Monitoring Guide*. In implementing the *Guide*, standards had to be derived to bridge the gap between specific monitoring practice required to meet state data needs and the general recommendations advanced by the FHWA. It was also necessary to produce standards that identified preferred methods where the *Guide* provided more than one alternative.

The state standards begin with general requirements for all traffic monitoring practices. Of these standards, the critical points adopted were restrictions on data manipulation, statement of confidence level and interval, unique road segment basis for traffic volumes, and establishing annual review and updating of standards. Each point is described below.

The state standards stipulate that missing or inaccurate data may not be completed, filled-in, or replaced for any type of traffic count, at any location, under any circumstance. This preserves the integrity of base data. Partial or incomplete data will be separately stored by type of data, and will be analyzed to quantify the errors that are associated with current imputation procedures.

The state standards require that all transmitted traffic counts and volume estimates must include a confidence level and interval. The specified system level confidence is 95 percent and the specified confidence interval is ± 10 percent. These statistics are calculated, as in the *Traffic Monitoring Guide*, from system level variability of data.

The standards identify that traffic summary statistics must be reported on the basis of "unique road segments." If two values of the same traffic volume summary statistic within a road segment have a volume difference that exceeds their combined confidence interval, the road segment is not unique. It must be divided into separate, unique segments and separate traffic summary statistics must be provided. This division prevents averaging highly variable traffic volumes, for example, as representative of a road segment, which results in the arithmetic mean being an inadequate measure of the central tendency of traffic on the roadway.

In New Mexico there are roads that primarily serve extractive industries. On these roads not only the volume difference but the load difference is important in discerning what is a unique road segment. For this reason, the standards identify that if two equivalent single-axle loading (ESAL) summary statistics within a road segment have an equivalent loading difference that exceeds their combined confidence interval, the road segment is not unique. In this instance it must be divided into separate, unique segments. This is an important element of the standards. It identifies, for example, that if separate segments are indicated, separate design solutions may be indicated.

Standards revision was made part of the general traffic monitoring standards. There will be an annual review of standards and their implementation. The same consultative process will be used as served the drafting of the standards. A standards compliance and revision mechanism, based on a government audit, was designed and distributed to all agencies involved in traffic data collection. The audit includes a record of implementation for each state standard and an equipment maintenance record. The standard audit will provide a check for data integrity. The equipment maintenance record will enable estimation of additional data collection attributable to anticipated equipment failure.

After the general standards are stated, standards related specifically to continuous automatic traffic recorders (ATRs) are discussed. The basic function of ATRs is to provide data that can be analyzed and grouped on common patterns for the development of adjustment factors. The adjustment factors may then be applied to coverage counts. Previous analysis of ATRs monthly, or seasonal, patterns in New Mexico identified that functional classification and seasonal variation are highly correlated. For this reason the annual and monthly adjustment factors are based on summary statistics from ATRs on the same roadway functional classification. In the same study of traffic statistical variability by functional classification, it was determined that individual ATRs effectively control volume factors on the same roadway for relatively short geographic distances. Beyond a 2-mile distance on the same roadway, except for lengthy, rural unique road segments, the mean statistic from ATRs on the same functional classification provides a more adequate count adjustment factor. This led to state standard restrictions on the maximum distance, on the same route, for which data from an individual ATR would be applied.

The state standards require an adequate sample of ATRs by functional classification. As importantly, it is required the sites be randomly selected within each functional classification. Over the years New Mexico has installed a variety of ATRs. In most instances this has not been a random process, but rather what is referred to as a "pseudorandomization" process: where there were road construction projects and an ATR was considered important, one was installed.

This practice has potentially introduced unknown bias into the mean statistics by functional classification. Under the state standards new permanent counters are required. The old counter data will also be collected. After the first year of enforcement of the standards, there will be an opportunity to measure the impact of pseudo-randomization of counter location by functional classification and volume grouping of roadways.

There is another opportunity to measure the impact of traffic monitoring practices other than the practices specified in the state standards. Under the general standards it was noted that incomplete data cannot be imputed. Incomplete permanent counter data cannot be used in computing average day of the week, month, or year in calculating AADT. The standards specify that monthly traffic summary data must be based on a representative sample of the days within the month, which must include a minimum of 2 days for each day of the week. Complete, standard data are stored in the primary file for calculating summary statistics.

The data from an ATR not meeting state standards, including complete data, will be excluded from calculating the mean summary statistics of their functional classification. These data will be separately stored in a research file. At the end of the first year of the state standards, and each subsequent year, it will be possible to evaluate the statistical significance of including

data that had been excluded. If merited, the standards may then be appropriately modified.

The principle adopted in the New Mexico state standards is clear: questionable data are excluded from traffic monitoring statistics until it is shown that their inclusion adds to rather than diminishes the quality of the analysis. All data are retained and stored for use in the primary file for computing traffic monitoring statistics or for use in the research file for data analysis and possible standards modification.

In keeping with this principle, other quality controls are identified within the state standards. Among these are

- When the same recorded traffic volumes, other than zero, occur at an ATR for four successive hours, an error message will be displayed and the day's data will be excluded from calculation. They will be separately stored in th research file for analysis.
- When 8 hours of successive zeros occur at an ATR, an error message will be displayed and the day's data will be excluded from calculation. They will be stored in the research file.
- If the daily directional total of an ATR is in the range of 60 to 79 percent of the total traffic for the same day, a data and ATR review message will be displayed. The data will be excluded from initial calculation and stored in the primary file only after operator review and acceptance.
- To provide the operator an indication of ATR correct monitoring, when the daily traffic volume for a given day of the week exceeds ± 2 standard deviations from the annual average day of the week for the same day, a warning message will be issued.

The intention of these standards is to ensure that suspect data are not automatically loaded into the ATR primary data base. Further, excluded data will be reviewed through the research activities of the department to help determine whether or not exclusion is appropriate.

The third section of the New Mexico state standards relates to volume coverage counts. Forty-eight consecutive hour counts, with direct computer interface fo the traffic monitoring data base, are specified. An adequate sample to attain the specified confidence requirements is calculated for the following functional classifications:

- Rural
  - — Interstate
  - — Principal arterial
  - — Minor arterial and major collector
  - — Recreational route
- Urban
  - — Interstate
  - — Principal arterial
  - — Minor arterial
  - — Major and minor collectors

Following the principle of excluding suspect data, and the standard prohibiting data imputation, if there are less than 48 hours of data, the count will not be included in the coverage sample. Incomplete data sets will be separately saved. At the end of the first year, and each subsequent year, it will then be possible to measure the impact of including various hours of imputed data, by alternative imputation techniques.

Vehicle classification counts are a subset of the volume coverage count program. The coverage count sites are randomly selected from all unique road segments. The number of counts is based on the variability of data by functional classification. Vehicle classification count sites are randomly selected from the coverage counts. This makes the count program more efficient: the same effort used for collecting classifications also collects vehicle volume for these sites. Two required counts are taken with one operation.

The classification counts are used in estimating the loop correction factor. The mean loop correction factor by functional classification is used. The loop correction factor from the classification subset will be compared with the factors from the ATRs on the same road classification. This will allow testing the assumption that the coefficient of variation for coverage count loop correction factor (based on shorter term, more extensive number of counts) will be lower than that of the ATR loop correction factor (based on longer term, fewer count locations).

In addition to nesting classification counts within the coverage count program, the New Mexico state standards nest the speed count program. Speed compliance monitoring will be based on 48-hour intervals, in both directions. Both speed and volume will be recorded so that volume can be used to either satisfy a required sample in the coverage count program, or to provide more current traffic count data for a segment in the data base. Noncoverage count site data provide a basis for evaluating noncount year functional classification growth factors.

The third nested count program is WIM. The WIM program is a subset of the classification count. As specified in the *Traffic Monitoring Guide*, a minimum of 90 sites are sampled for 48-consecutive hours, over a 3-year cycle. Thirty of the sample sites will be selected from the Interstate vehicle classification sample. Volume and vehicle classification data from the WIM program will be used to satisfy part of the vehicle classification and coverage count requirement.

After the count programs have been completed, traffic-flow maps are a primary source of data distribution in New Mexico. The New Mexico state standards clarify the way in which data are to be published. Traffic-flow maps will not use smoothing techniques. All volumes represented must, beginning with the second year of standards implementation, be based on count data.

During the phase-in of the standards, there will be some data that are not in compliance. The first year after adoption of the state standards, all traffic-flow maps may designate volumes in three ways:

1. Traffic volume with general confidence level and interval, which denotes the volume method, is in compliance with state standards.
2. Traffic volume in parentheses, which denotes the volume is based on count data for the segment, is not in compliance with state standards.
3. Traffic volume in brackets, which denotes that the volume estimate is not based on count data for the road segment, is not in compliance with state standards.

In the second year of implementation of the state standards, no estimated volume data may appear on the traffic-flow maps. In the third year of implementing the state standards, and all subsequent years, the only volumes designated may be those in compliance with the state standards.

The New Mexico State traffic monitoring standards include requirements for manual counts, other specific project counts, and traffic monitoring equipment. As a whole, the standards create the condition for equivalent data use statewide, for both the governmental and private sectors. The standards create the condition for understanding traffic data and their appropriate use.

BENEFITS FROM IMPLEMENTING STATE STANDARDS

There are three primary benefits from adoption of the state traffic monitoring standards. The first benefit, which has accrued through the development of state standards, is traffic data efficiency. Whether the data are collected by the state, city, or a consultant employed by a governmental agency, the data are standard and may be electronically collected and transmitted to the state traffic data base. This saves staff time and error in manual transcription of data, and provides a single traffic data resource for New Mexico.

The second benefit is systematic traffic data summarization and analysis. No matter how efficiently the data were transmitted, if mixed data were gathered, the traffic data base would be of marginal planning and engineering support. The systematic data collection and summarization practices provide equivalent traffic data. It is compelling to compare some current practices (which result in typical traffic data with no known accuracy, or accurate 90 percent of the time ± 100 percent), with standard-based practices. The present study and standards provide appropriate traffic data for highway planning and engineering activities.

The third benefit is ongoing traffic data research and development. Over the longer term, benefit is anticipated from data comparisons. With the standards implemented, on an annual basis the impact of random and pseudorandom ATRs can be calculated. The impact of excluding partial data can be evaluated. The impact of alternative imputation techniques, with various hours and days of data estimated, will be compared. The change in project selection, pavement design, and urban traffic network simulation may be evaluated with each proposed change in the state standards.

Each of these changes and each of these benefits are provided through statewide traffic monitoring standards. The potential exists for refinement of traffic monitoring practice through the development of consistent, comprehensive statewide traffic monitoring standards.

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Publication of this paper sponsored by Committee on Transportation Data and Information Systems.