Design, Development, and Implementation of a Statewide Traffic Monitoring System

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Statewide traffic monitoring standards were established October 1988, by the New Mexico State Highway and Transportation Department. The quantity of data to be tested for compliance with the standards required the design, development, and implementation of a computer-based data analysis system. The Traffic Monitoring System (TMS) is the mainframe software package developed to implement the data standards. The system was designed in the Statistical Analysis System (SAS) and installed June 1, 1989. The conceptual design of TMS and the SAS components are transferrable to other environments. The TMS is designed to process traffic volume, classification, speed, and weight data. There are four basic components of the system. A "User Interface and Automatic Initiation" component reports system condition and controls automatic data processing and report generation. The second component, "State Standards Edit Programs," validates raw traffic field data. The third component of the system is "Traffic Data Files." Standard traffic data are placed in the primary data files, and data not in compliance with the standards are stored in separate research files. The fourth component, "Report Generation Programs," produces required traffic monitoring reports. The TMS provides an efficient implementation of statewide traffic monitoring standards. The system preserves the integrity of the base data while meeting current reporting requirements. The TMS offers an opportunity for analytically addressing current and future traffic monitoring issues.

In 1986 the New Mexico State Highway and Transportation Department began a process of evaluating and upgrading traffic data applications. After review of initial efforts in 1987, it was demonstrated that a comprehensive study of traffic data collection, summarization, and analysis was needed. This study was undertaken by the department, in cooperation with the FHWA, and was completed in May 1988. The study identified the importance of equivalent traffic data for current planning and engineering data uses (*1*).

The importance of ensuring equivalent traffic data by defining and enforcing traffic data standards was the primary finding of the study. Study results, combined with FHWA's *Traffic Monitoring Guide*, led to development of the New Mexico State Traffic Monitoring Standards (*2*). The State Standards became effective on October 1, 1988, and are required on all New Mexico roads for which state or federal funds are used, or proposed to be used (*3*).

The 89 traffic monitoring standards address traffic volume, speed, classification, and weight data. The standards apply to data collected by the state, Metropolitan Planning Organizations (MPOs), county and city governmental agencies, and private consulting engineering firms. The quantity of data to be tested for compliance with the standards required the design, development, and implementation of a computer-based data analysis system.

The Traffic Monitoring System (TMS) is the mainframe software package designed by the Highway and Transportation Department to implement state traffic data standards. The TMS was developed by Chaparral Systems Corporation and was installed on June 1, 1989.

TMS was programmed in Statistical Analysis System (SAS), a software system for data analysis. SAS provides the capability for supplementing basic reporting functions with statistical studies of any level of complexity. SAS also provides the considerable flexibility necessitated by changes in technology and reporting requirements.

The system is designed to run as an application under the Digital Equipment Corporation (DEC) All-In-One package. Consequently, the user interface is specific to the DEC VMS operating system. However, the conceptual design of the system and the SAS components are transferrable to other environments.

The design of TMS addresses traffic monitoring activities from data collection to report generation. TMS processes digital traffic volume, classification, speed, and weight data, and also checks for compliance with state standards. TMS associates the traffic data collected with cumulative milepoint of unique road segments as defined in the department's Consolidated Highway Data Base (CHDB). TMS summarizes the data in a form that is appropriate for both reporting and research applications. TMS directly generates summary traffic statistics on daily, monthly, quarterly, and annual reports. TMS was designed so that each of these features are in an easy-to-use framework that require minimal operator training and intervention.

Implementation of the TMS design is identified in this paper. This implementation is described by reviewing the primary data principles on which the system was built; the basic components of the TMS; system operation; reports generated; and continuing system development.

PRIMARY TMS DATA PRINCIPLES

The Traffic Monitoring System was built on three primary data principles. They are security and truth-in-data, assuring

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data retention through system integrity, and automating the traffic data process as fully as possible.

Security and truth-in-data are important principles on which TMS was developed. Security ensures that the data are not modified, and that when data are summarized, the base data can be retrieved. Truth-in-data ensures that data users have identified what the data are, and how the data have been summarized.

An important driving force behind development of the TMS was the concept of data integrity. Consequently, both the raw data files and the SAS data files are read-only files. This avoids many problems associated with various users applying different estimation procedures for missing data. The TMS reports are also read-only documents which cannot be modified in the All-In-One DEC application. Additionally, sites with statistics based on actual observations are distinguished from sites where statistics have been estimated according to functional classification. Furthermore, the data must be protected through software system integrity. This was referred to as making the data and the system "bullet-proof." TMS incorporates numerous system integrity features in addition to data integrity. The TMS is designed to recover itself automatically, or with minimal intervention, in the case of catastrophic system failure. The system restart capability allows cumulative files and programs to be reset so they can be restarted to receive and store data, without generating duplicate data.

The third data principle of TMS is that the volume of data requires that most of the TMS work be done automatically. Each morning, a TMS job automatically gathers all of the traffic counts collected the previous 24 hours. These include Automatic Traffic Recorder (ATR), Automatic Vehicle Classification (AVC), and Automatic Vehicle Weighing (AVW) counts, and counts taken from portable devices. Portable traffic monitoring activities include coverage and special counts, speed counts, turning movement counts, and portable weigh-in-motion (WIM) counts.

These data are then automatically processed. This processing includes conversion to a standard format when necessary, editing for compliance with state standards, and summarization into the daily TMS cumulative files. After this processing has been completed, an electronic mail message is automatically sent to the primary TMS operator. This message is a single statement describing the results of the daily run. The operator can then get more detailed status information using the TMS menus. This information includes a detailed edit log which describes the status of each count or ATR file processed.

At the beginning of each month, a monthly processing job is automatically submitted, but in a "hold" status. This allows the primary system operator to release the job for processing when all data for the preceding month have been captured. The monthly run consists of edits for state standards, summarization into monthly TMS files, and monthly reports. The monthly reports are official TMS reports, which means that they are given "read-only" protection. A reader can not modify the contents of these files, which are available to anyone with All-In-One access.

The annual run summarizes the monthly data into annual TMS files, and generates the annual official reports. Additionally, TMS updates the department's CHDB traffic statistics, making them generally available. The annual reports are also official reports that are given "read-only" protection.

BASIC TMS COMPONENTS

The first component of the TMS is the User Interface and Automatic Initiation. This component controls the TMS. It initiates automatic operations and provides communications between the user and the computer software. It controls the automatic data processing and report generation procedures. Through the interface, the user also receives messages concerning system status. These include lists of data files received from the field, input data rejected and stored in a separate logical Research File as a result of noncompliance with state standards, and reports generated.

The second component of the TMS is the State Standards Edit Programs. New Mexico Traffic Monitoring Standards functionally require two separate SAS edit programs. The first looks at the raw traffic data from the field on a daily basis. Edit checks are applied to the data, site-by-site, to ensure that valid, consistent data are being received and that the devices in the field are functioning properly. The second program takes the daily data and computes monthly summary traffic statistics, which must also adhere to state standards. Both edits can be performed automatically, on a daily and monthly basis, and the results are communicated to the user through the User Interface.

In addition to the editing programs, the State Standards Edit Programs contain several other data manipulation programs. These carry out data reformatting, data identification, and file manipulation operations.

The third Traffic Monitoring System Component is Traffic Data Files. The traffic data are placed in one of more than a dozen SAS data files, depending on type (such as volume, classification, speed, and weight). Data elements within these files were chosen because of monthly or annual reporting requirements, or with the expectation that the elements would be significant in future research. All the raw input data are archived as well, recognizing that reporting or research requirements might change with time.

Report Generation Programs is the fourth component of the TMS. A set of monthly and annual standard reports were identified by the state as being necessary for either external or internal reporting requirements. Each report is generated by a SAS program, using the SAS data files as input. Reports may be produced either automatically at predetermined times, or manually through the User Interface. The user can view the report documents prior to be printed.

A new report can be added by creating a new SAS program and adding it into the User Interface. This is accomplished through the Technical Administration menus. Both the SAS primary and research traffic data files, and the raw input data, are available for research applications.

TMS OPERATION

Users interact with TMS through a menu-driven interface. The three sets of menus correspond to the three organizational roles required for TMS: user management, technical management, and system operations.

The User Management menus allow TMS responsibilities to be assigned to specific individuals. This function controls the routing of status messages to specific TMS personnel. User Management menus also contain the menus available to System Operations.

Technical Management menus provide the capability of configuring the TMS. Primarily, this involves the addition of reports and the control of numerous system parameters.

The System Operations menus and displays are illustrated in Figure 1.

The System Operator has four menu options. "Status monitoring" allows one to view the system log to determine the outcome of the automatic runs. "Reports" allows the generation of personal reports and the viewing and printing of both official and personal reports. It also has report indexing features. "Data files" allows the viewing or printing of raw data files, annotation of raw data files, and processing of coverage or other short-term count files. "Job control" provides the capability of releasing jobs in "hold" status.

The Status Monitoring display occurs when the STS option is selected from the Main Menu. (See Figure 2.) Each numbered line in the body of the display represents one of the components of the automatic processing runs. The overall outcome of each component is given in this display.

If the operator wants more information about the component, the item can be selected and a more detailed report (if available) will be presented. If the operator requires historical information, a specific component and a range of dates can be selected, and the system will display only that component for the dates requested.

The "Reports" selections shown in Figure 3 allow the generation of personal reports and the viewing, printing, and indexing of official reports. To generate a personal report, the information becomes a word processing document that can be printed, viewed, or edited from the word processing menu.

Official reports are viewed or printed through this menu. Each report has associated print options attached that cause it to be properly printed. For example, some of the reports are printed in landscape mode, if that is their proper orientation. These print options are controlled through the Technical Management menus.

The Index option allows the user to select a subset of the numerous reports for more convenient manipulation. This allows easy selection of the reports thus indexed for viewing or printing. (See Figure 4.)

This menu allows raw data files to be annotated, printed, or read. Annotation allows comments about a specific data file to be stored for future reference. For example, a count that is excessively high might have occurred on the day of a special event. This could be noted for future reference with this facility.

The files are printed or read in their source format. This allows easy determination of any technical problems resulting in improper file formats.

If coverage and special count or turning movement files are selected, the option is provided to process the files. If this option is selected, any coverage or special counts that have been uploaded since the last automatic run (or last exercise of this option) will be processed and the results made available through the "Reports" menu.

The job control menu allows the operator to release any jobs that have been submitted in hold status. The operator in this way controls when monthly and annual runs actually occur. (See Figure 5.)

If there are data whose collection has been delayed by technical problems, the operator can wait until the job has been released.

TMS REPORTS

The following reports are generated by the TMS. Most are designed to run automatically on either a monthly or annual basis. However, the user may run a report at any time through the User Interface, by specifying the desired time interval and site. Note that some reports use historical data, not just information from the current year.

1. Annual vehicle miles traveled (AVMT) by
   - Administrative classification,
   - Functional classification,
   - Vehicle and administrative classifications,
   - Vehicle and functional classifications in percent, by vehicle and functional classifications, and
   - Vehicle classification, by year.
2. Daily average vehicle miles traveled (DVMT) by
   - County and administrative classification,
   - County and functional classification,
   - District and administrative classification,
   - District and functional classification, and
   - Month with monthly variation.

```
------------------------------------------------------------
Operator Name      Primary System Operator     Mon 19-Jun-1989
                   Traffic Monitoring System
          STS  Status monitoring
          RPT  Reports
          DAT  Data files
          JOB  Job control

          Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 1 Main TMS menu.

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------------------------------------------------------------
                    TMS System Log Inquiry
------------------------------------------------------------
Event/Report              Date     Status  Text
1  DAILY EDITS SUMMARY    89-06-19 Info    Daily ATR data edits
2  DAILY TC-II CONVERT    89-06-19 Info    Daily TC-II data
3  DAILY TC-II COLLECT    89-06-19 Success TC-II consolidation
4  DAILY TC-III COLLECT   89-06-19 Success TC-III consolidation
5  DAILY CSC COLLECT      89-06-19 Info    No CSC data
6  DAILY TURN COLLECT     89-06-19 Info    No turn-mvmnt data
7  DAILY MPO COLLECT      89-06-19 Info    No MPO data
8  DAILY MESSAGE CHECK    89-06-19 Success Message status check
9  DAILY CHDB EXTRACT     89-06-19 Success Task Daily CHDB
10 DAILY EDITS SUMMARY    89-06-19 Info    Daily ATR data edits
------------------------------------------------------------
Event/Report:
Start Date:                          End Date:
Press RETURN to continue, or line number you want to select,
or EXIT SCREEN:
------------------------------------------------------------
```

FIGURE 2 Status monitoring (STS) display.

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------------------------------------------------------------
Operator Name    Primary System Operator    Mon 19-Jun-1989
                        TMS Reports
   SEL  Select    Folder:  AVMT
                  Abbrev:  AVMT BY V F CLASS
                  Title:  Annual Vehicle Miles Traveled by VT
                  Created:  1989-05-03
         G    Generate (personal report)
         R    Read     (official report)
         P    Print    (official report)
         I    Index    (official reports)
         Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 3 Reports (RPT) menu.

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------------------------------------------------------------
Operator Name   Primary System Operator     Mon 19-Jun-1989
                    TMS Data File Functions
        SEL  Select Counter Type:  TC-II RAW DATA
                   Location Code:  B74
                       File Name:  B74-1989-06-18-03-28.DAT
        A    Annotate
        P    Print
        R    Read
    Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 4 Data files (DAT) menu.

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------------------------------------------------------------
Operator Name    Primary System Operator      Mon 19-Jun-1989
                       TMS Job Control
        SEL  Select                 Job:
                                    Entry:
                                    Status:
        RJ   Release (start) current job
        C    Check job status
        Enter selection and press RETURN
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FIGURE 5 Job control (JOB) menu.

3. Annual Summary Statistics at ATR Sites by Year with Annual Variation
4. Annual Average Daily Traffic (AADT) by Vehicle Classification
5. Monthly Summary Statistics at ATR Sites by
   - Functional classification,
   - Administrative classification,
   - Day of week, and
   - Year with annual variation.
6. Hourly summary statistics at ATR sites by direction.
7. Traffic ratios and factors.
8. Current and three-year average monthly traffic ratio (MTR) by functional classification.
9. Current and three-year average annual average growth factors (AGFs) by functional classification.
10. Other ratios and factors—
    - Truck weight,
    - Equivalent single axle loading (ESAL) analysis, and
    - Equivalent single axle loading (ESAL) by functional classification.
11. Other Reports
    - Speed summary report,
    - Turning movement report,
    - Random samples for coverage counts,
    - District traffic maps, and
    - Municipal traffic flow maps.

The TMS provides direct generation of traffic reports, yet preserves data integrity and truth-in-data. The flexibility of the system described earlier identifies reports that can be modified and added as reporting requirements change.

Continuing Development of TMS

During the implementation and acceptance testing of the Traffic Monitoring System, additional system development was indicated. The areas of development in the coming year include volume and capacity analysis, conduct and enhancement of research activities, and interface between TMS and other information system tools.

One of the important areas of TMS continuing development is capacity analysis. In the coming year, existing road segment and intersection capacity analysis software will be integrated with TMS and CHDB. The integration will include retrieval

of TMS and CHDB data elements required to compute maximum service flow, volume and capacity and level of service. The data will be transmitted to the capacity analysis software and the capacity characteristics will be calculated. The resulting statistics will be loaded to the CHDB.

Development of TMS will include enhanced facilities for traffic monitoring research and development. In the coming year, TMS will provide alternative methods of traffic data summarization, while continuing to support the data summarization procedures as specified in the state standards.

Other system research refinements concern file identification and report printing. There is a need within TMS to develop a research data file location system which would include adding fields to report edit logs and development of a system for locating data files by content for research purposes. This enhancement of TMS would permit cut-and-paste to select types of data, facilitate nonprogrammer creation of a SAS file or files, and provide a menu of SAS routines to answer research data inquiries. There is a related need to develop an ad hoc report generator which would produce reports using the same cut-and-paste interface in the research data file location system. This additional system development would allow the results of traffic research inquiries to be quickly printed. These two research refinements are planned for TMS development in 1990.

TMS will be integrated with other data information systems. By 1991 TMS is planned to be integrated with the department's Geographic Information System, Global Positioning System, and statewide simulation model based on EMME2 and TMODEL2 operating in the VAX environment. These efforts will serve to further refine the location of traffic data, and to make the data more readily available for a variety of data uses.

SUMMARY

The TMS has provided an effective means of implementing the State Traffic Monitoring Standards. The resulting data base is appropriate for efficient, accurate information for current traffic data uses. System flexibility and facility for statistical analysis of the data are provided through development in SAS.

The TMS is also appropriate for examining traffic monitoring research issues, such as alternative data summarization methods. In the future, the system will be refined for research reporting, and integrated with other traffic software packages and information systems.

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