ABSTRACT

Research by Washington State Department of Transportation provides information about behavior of traffic for use in subsequent data collection and to improve predictions of vehicle volumes and truck weights used for highway design. Using previous obtained data, a system of SAS programs utilizes descriptive graphics interspersed with computation and inductive observations.

Twenty-four hour traffic profile models with hourly mean volumes of 12 vehicle types were developed from actual data. Models were put through a moving array matrix producing all possible consecutive 4-hour samples to develop expansion factors for converting short samples to 24-hour volumes by time of sample.

The entire process (which uses SAS means, plots, arrays, transpose, and macro) is broken down into a series of short programs with understandable steps not requiring complex mathematics or advanced SAS techniques. In the moving matrix, the late p.m. hours are wrapped around to add to early a.m. hours for complete 4-hour samples across all hours. Research is developmental during collection of a 3-year database.

STANDARD DISCLAIMER

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INTRODUCTION

Knowing what question to ask may itself be a product determined only after considerable effort. SAS graphics are valuable descriptive statistical tools to visualize concepts or patterns so that inductive decisions for further research can be made.

Transportation as an industry has a feast of available data but a famine of statistically valid, systemwide information. The state of Washington is trying to fill this void through a major systemwide effort to collect traffic data and build a statistically designed SAS database on a three-year repeating cycle.

These results are not a final product but a "snapshot" of some inductive research done on data collected to date using SAS on a mainframe. The report is written from a behavioral perspective.

Objective & Problem

The task of the study was to search already available data for ideas to improve predictions of traffic for state highway planning and design in the state of Washington. Specifically wanted was information to improve conversion of short 4-hour or 6-hour samples to estimate 24-hour totals. Another major component of the objective was to search for new ways of aggregating information regarding behavior of trucks and to determine optimum hours for sampling traffic to obtain the most representative truck mix. Trucks carry the weight loads whose long-term cumulative effect is responsible for most pavement damage.

Background

Highways have only one purpose and that is to carry traffic. Traffic itself is very dynamic and behavior changes take place in both quantity (number of vehicles) and quality (vehicle mix) due to variables such as hour of the day, day of week, season of the year, weather, and/or local events such as fairs or festivals. There is always the possibility of unpredictable, events such as accidents or acts of God. Excepting the unpredictable, many patterns can be determined quantifiably if we can gather optimum data samples to convert into long-range forecasts and generally make better decisions in planning for highways for future needs.

Much of the study was done on unbalanced, after-the-fact data which had been gathered for various purposes, and there was no opportunity to control for intervening variables or obtain representative stratified samples. Some locations were overrepresented while others had only a single sample. Only midweek traffic counts were used because of lack of weekend data.

The data used for this report originated from 331 24-hour traffic counts with 26 variables each hour (12 vehicle types plus identifiers). These are put through a process using a series of PROC MEANS to eliminate uneven sampling so that each of the 144 locations would have equal weight. The 12 vehicle classes are further reduced to six groups of vehicle types across eight highway functional classes. The truck groupings illustrate those showing clear-cut behavior patterns.

APPROACH STRATEGY

For this applied research, an inductive type of approach was used. Here clues obtained from some analysis lead us to develop other approaches or ways to get to the desired results. A couple of false-starts took place which showed us that some prevailing myths or pet theories needed to be discarded. The following is a summary of the most notable features.

The overall system outlined in this paper uses a network of SAS programs which produce graphics for visualization and decision-making purposes. Tables of expansion factors from a moving sample matrix were then developed for application to highway design.
SAS PROGRAMS (Descriptive)

Location Models and Traffic Profiles

TRACOUNT: This SAS program sets up the master SAS research data base with all 24-hour traffic counts classified by 12 vehicle classes. Files are created with each location's hourly mean averages for (1) season, (2) year, (3) location, and (4) 24-hour mean totals for each of the 12 vehicle classes. Each file is computed (2) year, (3) location, and (4) 24-hour mean totals for each location's hourly mean averages for: (1) season, (2) year, (3) location, and (4) 24-hour mean totals for each of the 12 vehicle classes. Each file is computed from the mean average of the previous level.

TRAPLOT: Plots traffic (all vehicles and all trucks) for each hour of the day at a location and also shows the 24-hour average. From these plots it is possible to visualize behaviors and the differences between trucks and nontrucks at different times of the 24-hour day.

FINDINGS FROM TRAFFIC PROFILES

This study focuses on the dynamics of the daily cycle in order to determine how to translate samples into 24-hour data for predicting truck volumes. The term "traffic" in this context refers to all vehicles including trucks. The term "trucks" includes all dual-tired vehicles, excluding buses. In the plots below, the volumes are on the vertical scale and the time (hours 0 to 23) on the horizontal scale. Volume scale will vary.

For each location in the study a location model was built which averaged the multiple samples by hour. A traffic profile of mean volume by hour was then built in which traffic groups were plotted and analyzed to determine the form of the daily distribution at each location. Four main types emerged with some locations having pronounced configuration of specific type, although a number of stations have characteristic of more than one type. An example of each type is illustrated. The four most notable types are:

- Type 1 -Bimodal, double peaks,
- Type 2 -Afternoon High, single peak,
- Type 3 - Bell Shaped, and
- Type 4 -Multipeaked or Broad Plateau.

At all locations there is a nadir point about 0200-0300 hours. Most volumes increase around 0600, have a period of activity lasting through 1700 hours with a decline after that. The rate of decline in the afternoon may be more rapid than the rate of increase in the morning or vice versa. The following graphs show volumes by hour for all vehicles (upper curve), hourly average of all vehicles (straight line) and all trucks by hour (lower curve).

Type 1 is the familiar "bimodal" configuration with two clearly defined peaks in the a.m. and p.m. during peak "rush hour" traffic. Type 1 is almost always located in or near large urban areas or on rural routes to large employment industries. This location is an urban interstate, residential-type area.

Type 2 shows an "afternoon high" profile with one major peak in the late afternoon. This type does not show a pronounced morning peak. Traffic starts increasing about 5 to 6 a.m. and gradually increases hourly (with minor variations) to a maximum during the late afternoon when it decreases rapidly. This is a rural principal arterial location.
Type 3 profiles tend to a "bell-shaped" curve with a gradual smooth increase and decline. There may be a general plateau of several hours from midday to late afternoon, or the shape may be rounded with high traffic at early afternoon. This profile appears in rural areas. This is a rural interstate, distant from large urban areas.

Type 4 profiles tend to have "multiple peaks" or a broad plateau, sometimes both. The plateau is broader than that of Type 3 and occurs from early a.m. to late p.m. usually with a sharp rise or fall immediately before and after the plateau. In the example the lower curve shows trucks to be a major driver of the traffic profile. This is a rural principal arterial logging area on the Olympic Peninsula.

FINDINGS FROM TRUCK PROFILES

Truck profiles were plotted for all of the location models. The passenger vehicles are omitted and the scale expanded. The term "trucks" refers to all dual-wheeled trucks excluding buses.

The shape of truck distribution does not usually follow the vehicle distribution and some locations may have a "morning high" of trucks with an afternoon high of vehicles. Truck profiles are generally somewhat bell-shaped, however, they may be patterned like any of the four all vehicle patterns described above. Generally, the truck day is compressed into a narrower business time span—increasing after morning traffic starts and declining before the evening decline of nontrucks. This reflects the business use of trucks.

INTERACTION BETWEEN TRUCKS AND NON-TRUCKS

In the graph below, hours are plotted on the horizontal scale and volumes on the vertical. Trucks show as the dark area above the base line and again in the dark area above the nontrucks (nontrucks are plotted from the base line also). The average 24-hour increase due to trucks is shown in the speckled band—the difference between nontrucks and all vehicles. Reference lines at 600, 1200, and 1800 hours show the 6-hour increments usually sampled.

Chart C-1 - Effect of Trucks on Traffic Urban Interstate near Olympia, Washington

From the discussion above and the examples, it can be seen that while traffic is composed of trucks and other vehicles, the activity of each can follow a different pattern. These patterns of behavior must be determined individually to be predictable for highway design.

BEHAVIOR DIFFERENCES IN TRUCK TYPES

In the following graph, the non-trucks (passenger vehicles) are removed and trucks are divided into three groups: single units, double units (a single unit with a trailer), and triple units (a single unit with two trailers). The behavior of each type is different.

Chart C-2 - Single Unit and Combination Trucks Urban Interstate near Olympia, Washington
Single units are not present at night—they are seen almost exclusively during business hours. Double units may be present at night, and have a larger, more extended increase during the day. Triple units have a steady level during all hours of the day or night. The location is the urban interstate outside of Olympia between Seattle, Washington, and Portland, Oregon. The model is based on seven counts at the location.

The constant level of triple-unit trucks is characteristic of all counts done on interstate locations in Washington between two very large cities, such as Seattle to Spokane or Seattle to Portland. The constant level indicates they are not concerned with business hours, and it can be inferred that they are hauling to 24-hour depots.

To summarize: 1) There is a separate component of trucking engaged in round-the-clock long-distance hauling whose volume is nearly constant day and night. This component is made up of combination trucks only (doubles and triples). 2) Another component is the daytime business trucking which is made up of smaller trucks (singles and doubles). These two components are each engaged in different behaviors and should be estimated separately for predictive purposes.

LOCAL VS. LONG-DISTANCE TRUCKING ON INTERSTATE HIGHWAYS

For purpose of estimating local versus long-distance large trucks, it may be assumed that daytime volumes of long-distance trucking are at least equal to the nighttime volumes (or that long-distance shipping remains constant around the clock). Local business trucking is added onto the steady volume of round-the-clock trucking. This is shown in cross-hatch on Chart C-3.

INDUCTIVE RECOMMENDATIONS BASED ON TRAFFIC PROFILE FINDINGS

1. From the discussion above and the examples, it can be seen that while traffic is composed of trucks and other vehicles, the activity of each can follow a different pattern and must be analyzed differently for purposes of predictions for highway design.

2. In addition to the separation of trucks and non-trucks a distinction must be made regarding locations which have round-the-clock night trucking.

3. Business trucking (daytime) must be analyzed differently from the component of round-the-clock, long-distance hauling because the ratio or mix of daytime trucks differs due to use of smaller trucks for daytime businesses and larger for long-distance hauling.

4. Triple unit trucks (where they exist) are engaged in a different behavior than trucks doing daytime business. This is seen by a constant volume of round-the-clock hauling. It is estimated that there is a constant level of double units engaged in this type of hauling also.

5. The study should proceed to determine expansion factors based on sample/24-hour volumes with each vehicle type isolated from the rest of the traffic mix as an independent variable. Factors should be simple multipliers based on hours at which the sample was taken.

IMPLEMENTATION OF RECOMMENDATION NO. 5

Using knowledge acquired from the plots of traffic and truck groupings, the study focused on expansion factors for individual vehicle groups. Trucks were grouped by number of units rather than size or numbers of axles. The following SAS programs produce factors based on data to date which is still one year short of being a full statistically designed data base for the entire state. When complete, further refinements will be possible.

SAS PROGRAMS (Factors for Traffic Prediction)

The Moving Sample Array Matrix

TRAC4MAT: A 4-hour moving array matrix is used to determine all possible four consecutive hour samples in 24 hours. The last three hours before midnight are wrapped around to the first three a.m. hours to obtain 24 complete sets of 4-hour samples. In the matrix, a single hour is replaced sequentially every hour and the four hours of volumes are summed for each vehicle class. Yielding the "S" variables ("S" for sample). (Program uses ARRAYS.)
At this point we have 24, 4-hour samples for each of 12 vehicle classes at 144 locations (61,672 samples). Before developing the factors for this report, the 12 vehicle classes were composited into six vehicle groups for which information is wanted, and the 144 locations were combined by means process into the eight federal highway functional classes. The six groups were determined from behavior patterns seen on the earlier plots. They are:

- Single Axle Trucks: All Trucks
- Double Axle Trucks: Non-Trucks
- Triple Axle Trucks: (Passenger Vehicles)
Traffic Expansion Factors--4 Hours to 24 Hours

TRAC4FAC: Compute expansion factors which are simple ratios of 24-hour total volumes (the "T" variables from file developed in TRACOUNT) to 4-hour samples (from TRAC4MAT). When applied, the 24-hour volumes will be the "expected" while the new 4-hour samples will be the "actual." (Program uses PROC TRANSPOSE, MACRO, MACRO VARIABLES.)

Application of Factors is as follows:

4-hour actual volume \times \text{Expansion Factor} = 24-hour estimate volume

Where Expansion Factor is selected from a table for the appropriate vehicle or vehicle group by time of sample and functional class of the highway.

GRAPHICS USE FOR VOLUME VISUALIZATION

The type of research described in this report helps to understand and visualize with graphics the makeup and patterns within a single day of the 365 days in the plot below. This plot, done in color with SAS/GRAPH 3D procedure, shows traffic volumes at a single location for every day of the year. The pattern shows increased volumes on weekends and during summer months. Highest volumes (peaks) take place immediately before and after major holidays. This location is a recreational area as well as a major interstate route across the Cascade Mountains which divide eastern and western Washington. The pass, with an elevation of 3,022 feet, is kept open year round except for brief occasions of extreme weather. Similar plots at major urban locations show quite different patterns with depressions on major holidays rather than peaks.

These volumes are collected by permanent recorders that count vehicles by hour using induction loops set in the pavement. The data is transferred monthly by telemetry to the Washington State Transportation Data Office in Olympia where it is used to monitor seasonal changes and annual growth of traffic. At this time, it is not possible to obtain this data classified by vehicle types and classification must be done either manually by trained personnel or by using temporary classification equipment which must be frequently monitored. This is the type of data collection which provided the base data for this research.

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