Augmented Weigh-in-Motion System for Traffic Data Collection and Analysis

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Comprehensive traffic loading data are essential for planning, designing, and maintaining highway systems. Two augmented weigh-in-motion (WIM) systems have been installed in the southbound lanes of US-59 in east Texas for the purpose of collecting and analyzing traffic data. An augmented WIM system is composed of an inductance loop detector, a weighpad in each wheel path, an infrared sensor unit for each lane, and two thermocouples. The weighpads in each lane are staggered longitudinally to measure speed and distance between axles in addition to wheel weights. The infrared sensors are set up in such a way that an infrared light beam passes just above the pavement surface. This light beam is blocked by the outside tires of vehicles traversing the weighpads. The lateral position of the tires can be determined and single or dual tires can be indicated. The two thermocouples measure the air and pavement temperatures hourly. Traffic data were collected continuously throughout 1993. Speed, volume, equivalent single-axle loads, lateral position, and temperature data were analyzed to find weekly and monthly trends. The data analysis is also organized by vehicle class and by lane.

Comprehensive traffic loading data are essential for planning, financing, designing, constructing, operating, and perpetuating all highway transportation facilities. Such data are needed to characterize and quantify the operational loads (traffic volume and speed) as well as the structural loads (tire forces acting on pavements and bridges) that will be imposed on each road segment in future years.

During the past three decades, weigh-in-motion (WIM) technology has advanced to the state that analysis of the dynamic forces applied by the tires of a moving vehicle to a measuring device can be used to estimate the gross vehicle weight (mass) and the tire loads of the static vehicle within tolerances that are adequate for collecting statistical traffic data and for aiding enforcement (by sorting suspected overweight vehicles from the traffic stream). Modern WIM systems typically include multiple vehicle-presence sensors and a pair of wheel-force transducers in each highway lane. They are capable of producing the following data items on-site, in real time:

- Wheel load,
- Axle load,
- Axle-group load,
- Gross vehicle weight,
- Speed,
- Center-to-center spacing between axles,
- Wheelbase (frontmost to rearmost axle distance),
- Lane and direction of travel,
- Date and time of vehicle passage,
- Sequential vehicle record number, and
- Site identification code.

Historically, an array of vehicle-presence sensors (inductance loop detectors) surrounding the side-by-side wheel-force transducers in each traffic lane have been used to sense the relationship of time and longitudinal position of each vehicle as its tires cross the transducers. The algorithms that use the sensed information to calculate speed, axle spacing, and wheelbase usually have been based on the assumption that the vehicle moves at a constant velocity while it passes over the WIM system sensors. When the vehicle is accelerating or decelerating, the values computed with these algorithms are in error.

Hardware and software for the augmented WIM system described in this paper were supplied by PAT Traffic Control Corporation to meet a specification of the Center for Transportation Research, University of Texas. This unique system uses a sensor arrangement that teams one vehicle-presence sensor with two staggered wheel-force transducers in each traffic lane; this alleviates the need for multiple vehicle-presence sensors and overcomes problems associated with computing the longitudinal dimensions of an accelerating vehicle. The system also incorporates a modulated infrared light beam sensor to provide information about the lateral position of the tires on each vehicle in the traffic lane and whether there are single or dual tires on each axle. In addition to providing statistical data about the location of tire loads on the pavement surface, these lateral position data can be used to identify the tires on vehicles that are partially off the weighpads, and thereby reduce mistakes in interpreting associated tire-force data to estimate weight. Additionally, air temperature and pavement temperature are sensed and recorded periodically at each site.

The system was installed at two pavement test sites near Lufkin, Texas, in the two southbound lanes of US-59 in late 1992 and early 1993. Continuous records have been made of all vehicles, including passenger cars, since that time. After initial adjustment and calibration, the PAT DAW100 augmented WIM system has performed very reliably. Minor adjustments were made to calibration settings at one site after 9 months, following multiple passes of two test trucks. Slight rutting of the pavement surface near the weighpads had occurred in the test section. Except for a few days, the infrared light beam sensors have functioned continuously. On two occasions—after 27 months at one site and 12 months at the other site—the two bolts 9.5 mm (3/8 in.) in diameter used to hold the sensor-source housing (described in the next section) to its base were sheared off. Two shear pins 9.5 mm (3/8 in.) in diameter were added to each housing to overcome this problem. The sensor-receiver units, located just off the shoulder, have been hit by an errant vehicle or a mower twice. Data presented in the following sections of this paper derive from the augmented WIM system.

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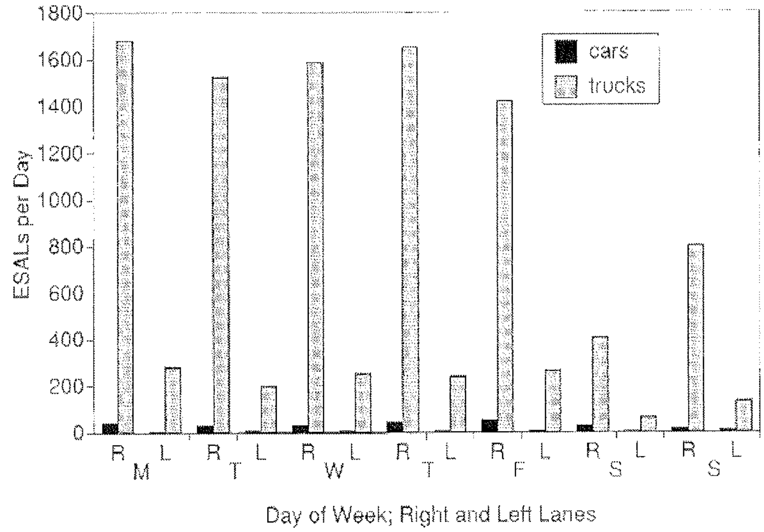

FIGURE 3 Weekly ESAL trends.

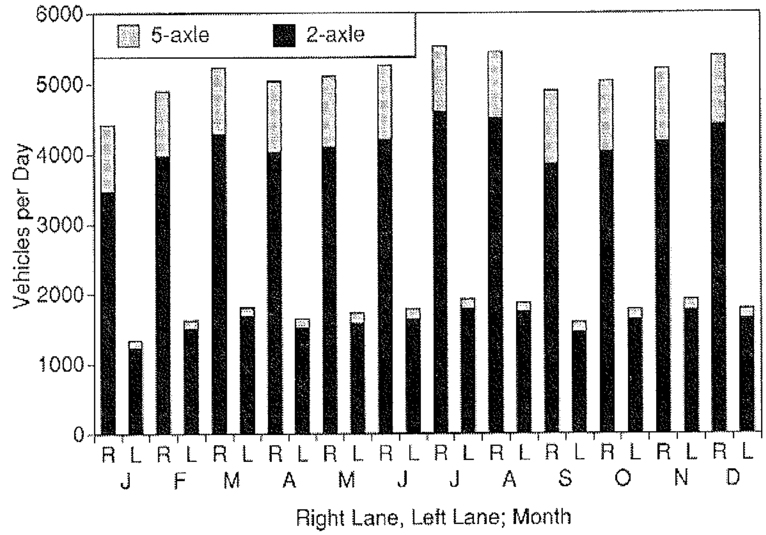

FIGURE 4 Monthly volume trends, 1993.

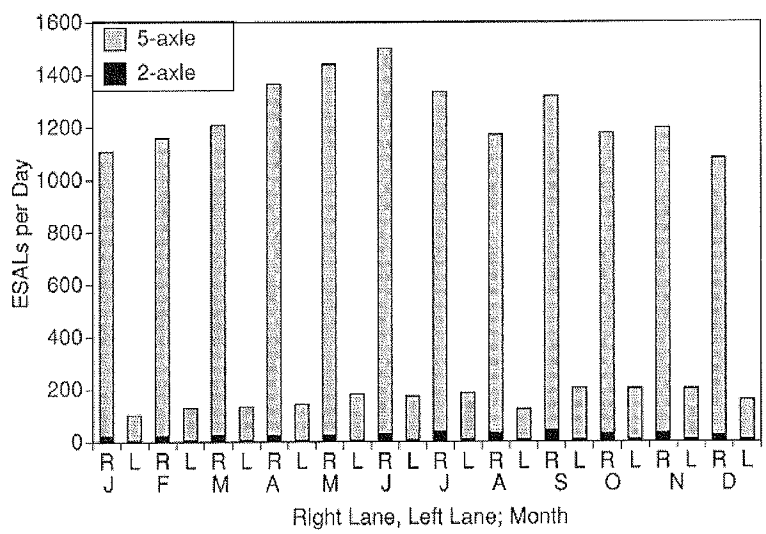

FIGURE 5 Monthly ESAL trends, 1993.

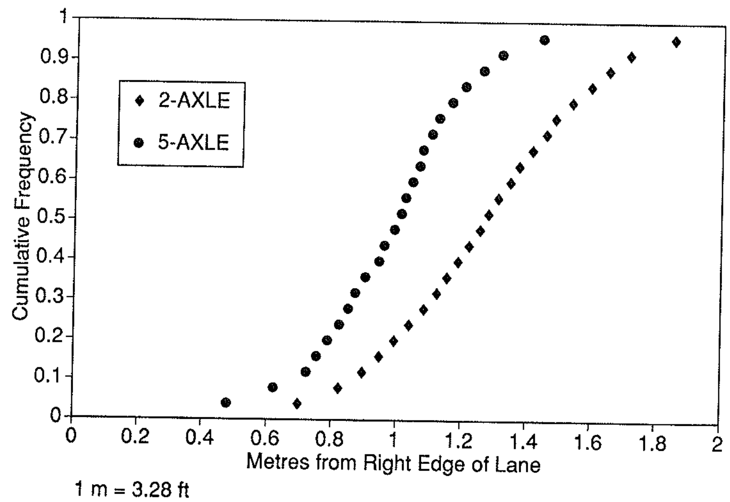

FIGURE 6 Lateral position distribution for right lane.

Lateral Position Trends

The median value for lateral position of front tires on two-axle vehicles in the right lane was 1.3 m (4.2 ft), as shown in Figure 6. For five-axle vehicles in the right lane, this value was 1.0 m (3.2 ft). In the left lane the lateral position for two-axle vehicles was 0.9 m (2.8 ft), for five-axle vehicles, it was 0.5 m (1.5 ft) (Figure 7). In the right lane the lateral position is measured from the right edge of the lane. Vehicles with the right front tire on the 3-m (10-ft) shoulder would, therefore, have a negative lateral position. If the right tire were on the stripe, the lateral position would be zero. If the right tire were in the center of the lane or farther from the right edge, it would not block the infrared light beam, the time interval would be zero, and the lateral position would be calculated as 2 m (6.5 ft).

In the left lane, the lateral position measures the distance from the left front tire to the left edge of the lane. If the left tire were on the 1.2-m (4-ft) shoulder, the lateral position would be negative. Since trucks are wider, they tend to travel closer to the shoulder than cars. Vehicles in the left lane tend to travel closer to the left shoulder than vehicles in the right lane travel to the right shoulder. This may be because vehicles tend to pass on the left and leave more space on the right side for vehicles traveling in the right lane.

Temperature Trends

Temperatures were recorded beginning in April 1993; the monthly averages are shown in Figure 8. July was the hottest, with average daily maximums of 43°C (110°F) for air temperature and 49°C (119°F) for pavement temperature. The average minimum temperatures for July were 23°C (74°F) for air and 32°C (89°F) for pavement. December was the coldest month, with average daily minimums of 5°C (41°F) for the air temperature and 11°C (51°F) for the pavement temperature. The average maximum temperatures for December were 21°C (70°F) for air and 20°C (68°F) for pavement. The average pavement minimums and maximums were always higher than the corresponding air temperatures except for November and December, when the air maximums were slightly higher.

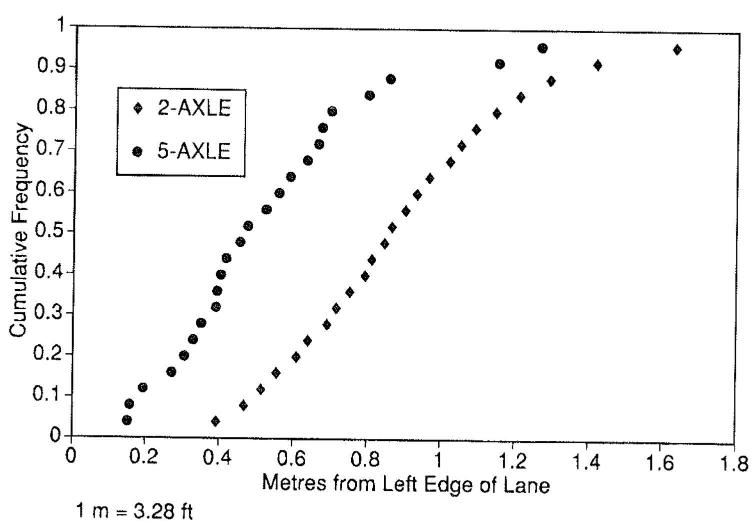

FIGURE 7 Lateral position distribution for left lane.

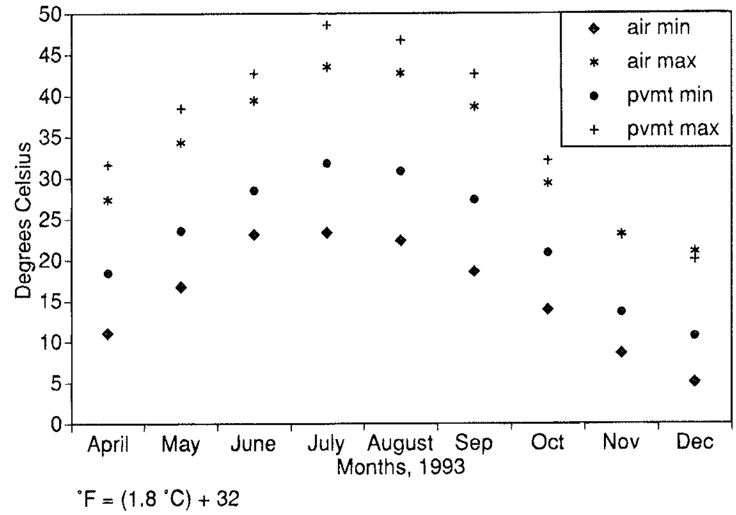

FIGURE 8 Average daily temperature extremes, 1993.

The air temperatures are somewhat high because the thermocouple for the air is only partly shaded.

CONCLUSIONS

An important feature of the augmented WIM system is the staggered weighpads, which minimize the number of sensors needed to measure vehicle speed and calculate axle spacing, even for accelerating vehicles, in addition to estimating wheel loads. Another feature is the infrared light beam sensor unit for each lane, which makes it possible to estimate the lateral position of the front tire on each vehicle with respect to the outside lane edge; it can also be used to determine whether the wheels on each axle have single or dual tires. The infrared sensor units are rugged, low cost, and low maintenance. Two thermocouples are used to collect hourly air and pavement temperature data.

Two augmented WIM systems were installed in the southbound lanes of US-59 in east Texas in 1992. Traffic data have been collected continuously since December 1992. A nearly 100 percent sample of vehicles for 1993 was used to find weekly and monthly trends and to characterize operational and structural loads on the rural roadway section. Representative and timely traffic and climatic data such as those collected by the augmented WIM system are needed to plan, design, operate, and maintain every highway.

ACKNOWLEDGMENTS

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REFERENCE

1. *National Climatological Data, Texas*, Vol. 98. National Climatic Center, National Oceanic and Atmospheric Administration, Asheville, N.C., 1993.

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