grade standards.

The available data on these methods of producing fuel conservation are quite scattered. For example, Claffey (Ref. 4) reports a 50 percent increase in fuel consumption on badly broken and patched asphalt when compared to fuel consumption on a smooth pavement. On the other hand, roughness does not enter into the computations of Hide et al (Ref. 5) when estimating the fuel consumption of vehicles on paved roads.

Summary

From this brief review on the methods available for conserving petroleum used for transportation, it is clear that significant fuel savings can result from carefully planned programs. However, care must be exercized when applying the information from other nations to the conditions in Brazil. The best use of the available data would be to produce a cost effectiveness study based upon the demand for transportation in Brazil and the unit cost or savings studies from foreign sources, adjusted for the transportation system in Brazil. The accuracy of such a study will be greatly improved when the results of the current highway user cost study are available.

AXLE LOADS

Accurate axle-load data are very important in the determination of pavement performance relationships; therefore, axle-load distributions and average load equivalency results for the pavement test sections are being determined from vehicle weighings measured with portable scales and the weigh-in-motion system.

Collection with Portable Scales

Vehicle wheel weights are obtained using two General Electrodynamics Model MD-400 portable scales. A level stretch of road (grade less than 1 percent) with good sight distance is selected in close proximity of the pavement section. The scales are then placed on the roadway and one lane is blocked off to permit measurements as shown in Figure 29.

To ensure that all wheels of one axle group are at the same height, wooden spacers (wooden beams the same thickness as the scales) are used before and after the portable scale in a longitudinal direction. The vehicle wheels thus first pass over the wooden spacers and then onto the scales. The two scales are placed so that both weigh one axle at the same time.

At each site, measurements are obtained during a 5-day period, generally from Monday to Friday. Because of safety considerations and to facilitate reading the scales, measurements are only conducted during daylight hours. On roads carrying less than about 800 vehicles per day, vehicles travelling in both directions can be handled with the scales located in one lane. For roads carrying heavier traffic it is necessary to measure only one direction per day, while the other direction is measured on the following day. Vehicles are sampled during peak hours to minimize delays and thereby maintain the goodwill of long-distance haulers. Thus no more than two vehicles are kept waiting at any single time.

Portable Scale Results

The percentage of axles laden above these legal limits were determined by traffic direction at a number of weighing locations.

The legal limits set by DNER which are in force in Brazil are the following:

Single rear axle	10000 kg
Tandem rear axle	17000 kg
Triple rear axle	25500 kg

The frequency of various increments of overloading by location-direction are shown in Figure 30.

From 10 to 35 percent of single rear axles are over-

Figure 29 - Axle Weighing with Portable Scales

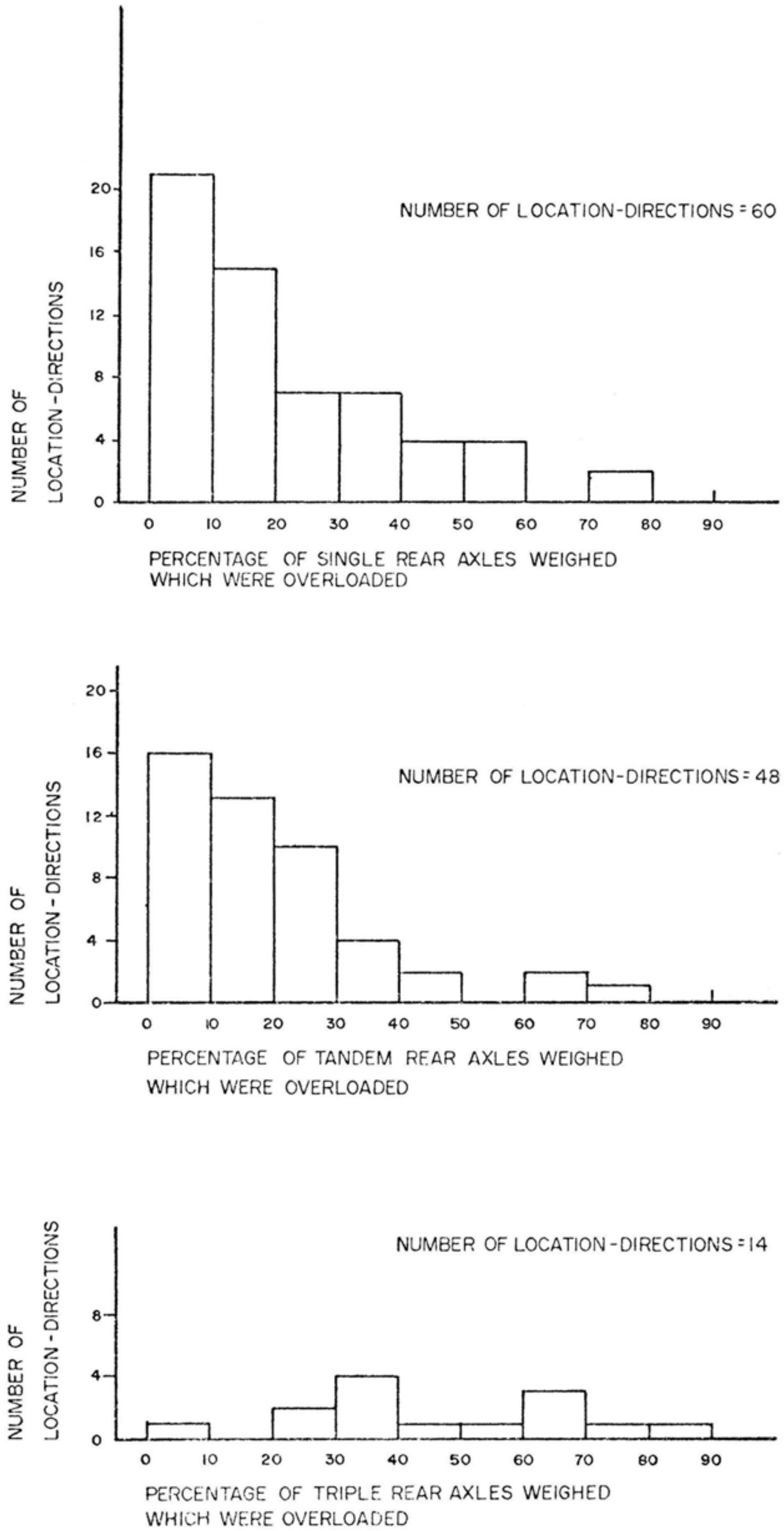

Figure 30 - Distributions of the Percentage of Rear Axles Weighed for Vehicle Sample Sizes Greater than 10.

laden, depending on the type of road traffic. Some cases have been recorded in which from 40 to 80 percent of the single rear axles are overladen. These are associated with the sand, gravel or ore haul routes. A trend similar to the single rear axles is apparent for the tandem rear axles on the sand, gravel and ore routes. The percentage of overladen axles lies between about 5 and 20. This reduction in the number of overladen axles could be ascribed to the fact that vehicles with tandem rear axles are generally used for long-haul transport, and consequently they would pass at least one of the weigh bridges, which are located along the main haul routes. Although the sample sizes of vehicles with triple rear axles are relatively small, about 30 percent or more are overladen.

Weigh-In-Motion System (WIM)

The WIM system measures vehicle weights while the vehicles are travelling at normal highway speeds. It uses two transducer units, which are built into the road in each wheelpath of a lane, and induction loops which serve as presence detectors and which also measure vehicle speeds.

The installations are made on tangential sections of road which have a grade of less than 1 percent, a smooth surface, and very little transverse deformation, to avoid problems as a result of dynamic forces. Six installations have been made similar to the one shown in Figure 30A.

To initiate measurements, the transducers are placed into the frame and the wires to the control box are fixed to the transducers, and the computer is connected to the control box. After completion of testing, the transducers are removed and replaced by dummy transducers.

Data collected at two WIM sites were analyzed to give a frequency distribution of axle loads. A computer program, which uses the magnetic tape as input, uses either the class of vehicle written onto the tape by the operator, or the axle configuration and spacing to distinguish between the different vehicle classes.

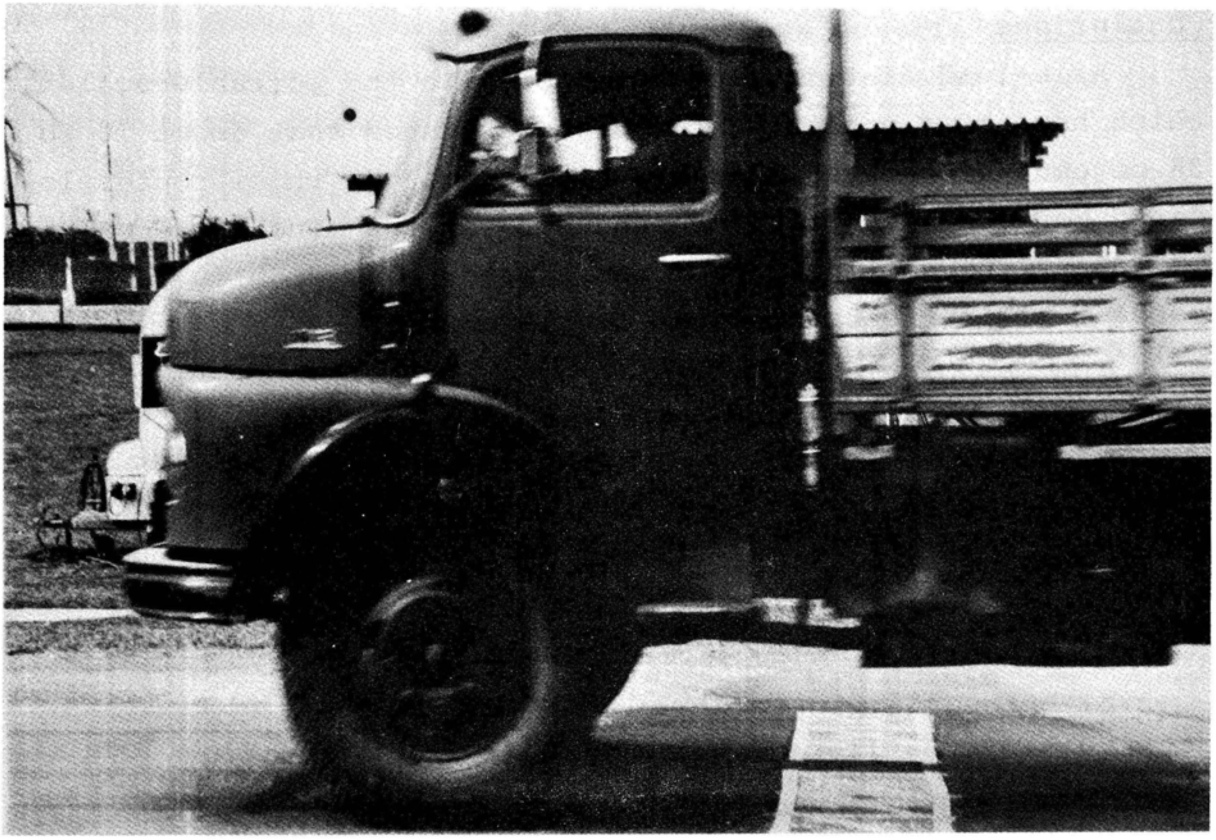

Figure 30A - Vehicle Weighing with Weigh-in-Motion System

A summary of data produced at the two WIM sites again illustrated the severity of overloads. Twenty percent of approximately 4900 single rear axles were overloaded as were 40% of some 2000 tandem rear axles card 38% of over 200 triple rear axles.

Conclusions

Axle-load distribution obtained with the portable scales, which have been presented for 34 sites, show that about 10 to 35 percent of the vehicles are overladen. On those routes located between the gravel or sand pit, or the mine where ore is mined and the destination of these materials, from 40 to 80 percent of the rear axles are overladen.