consumption. The purpose of this experiment is to examine the effects of extreme curvilinear alignment on fuel consumption. Eight test vehicles provided the data collected on the two 8% gravel sections. Test runs were made in both directions in the empty and laden condition. Since one of the sections was a tangent and the other had a very small radius curve, fuel consumption differences could be compared between the two horizontal curvature extremes.

It is difficult to make firm conclusions about the results of the analysis-of-variance procedures because of the limited degrees of freedom in the error term and because of the inference restrictions. The experiment cannot be viewed as a definitive study of the effect of horizontal curves on grades. However, within the scope of this experiment, the effect of horizontal curves appears to be minimal. Since this test was conducted using extreme conditions of horizontal curvature and grade, and for these conditions the largest mean difference in fuel consumption was only 3%, it may be concluded that it is not economical to experiment further on the effects of curves on fuel consumption. Therefore, the satellite study to further investigate the effect of horizontal curves on fuel consumption, FCS-2, will not be conducted.

FUEL CONSERVATION

In the process of evaluating the state of the art in the area of fuel-consumption experiments, several factors were identified which should be considered in establishing fuel conservation policies.

The information reviewed originated in other countries, and has been collected and summarized by project staff. It may be placed in two basic categories: studies to develop unit costs savings of motor vehicle operation, and those that may be described as cost effectiveness studies.

Since the highway transportation system is unique for each country, some difficulty arises when trying to transfer this information across international boundaries. This is particularly true for cost effectiveness studies since they are dependent on the transportation demand pattern. Cost effectiveness studies are the result of computing total costs or savings for a given strategy based on an estimated transportation demand level, and unit costs or savings information.

On the other hand, because there are some common denominators in all transportation systems, the unit costs studies may have a certain amount of international application. Therefore, emphasis is placed on reviewing unit costs or savings studies, but cost effectiveness studies are cited to give examples of the potential impact of various petroleum conservation programs.

In order to affect the amount of petroleum required for transportation it is necessary to alter one or more of the three components of the transportation system. These components are 1) the vehicle, 2) the roadway and 3) the user. To alter the petroleum requirement, one may use technological, legal, or economic means, to reduce the demand for transportation, or increase the efficiency of the transportation system.

User Considerations

In general, the highway user's attitude about transportation convenience must be altered in order to affect petroleum conservation. Examples of changing user attitudes include:

a) encouraging the use of car pooling and mass transit for routine trips such as going to and returning from work;

b) encouraging use of reduced speeds on rural roads,

c) encouraging people to walk on short trips (less than 2 km), rather than drive; and

d) encouraging truck operators to switch off the motor when stopping for more than six minutes.

Cost effectiveness studies of these types of fuel conservation measures have been performed in the United States and are shown in Table 6 as an example of the amount of savings which

TABLE 6 - COST EFFECTIVENESS OF VARIOUS USER PROGRAM FOR PETROLEUM CONSERVATION IN THE UNITED STATES (Ref. 3)

Option	Fuel Savings as Percent of Direct Transport Energy		Likelyhood of Achievement
	1980	1990	
CAR POOLING			
47% Participation	1.9	1.5	Medium
70% Participation	4.9	3.8	Low
SPEED LIMIT (88 km/h)			
Cars	1.2	0.9	High
Trucks	0.5	0.6	High
BETTER VEHICLE MAINTENANCE	0.7	0.6	Low
IMPROVED DRIVING HABITS	2.4	1.9	Medium
URBAN TRAFFIC FLOW	0.4	0.9	High

can be obtained. Since user attitudes are probably different in the United States and Brazil, the figures given in the table cannot be used here. However, a study of the situation in Brazil would probably show high potential savings through the use of these measures.

Vehicle Considerations

It is well accepted that through technological means, the efficiency of the modern passenger and cargo vehicle may be greatly increased. Table 7 is a summary of methods which have shown potential for saving fuel. Care must be taken when applying these results to Brazilian conditions. For example, generally the savings shown by reducing aerodynamic drag of trucks is based on a study of trucks with enclosed trailers. Since this type of trailer is not predominant in Brazil, the fuel saving potential in this case will be different.

Table 8 gives an example of the potential energy conservation available in the United States for various methods of increasing the efficiency of vehicles.

Roadway Considerations

Petroleum conservation may be obtained through improved roadway design and planning. The two main areas for potential savings are improving the traffic flow in urban areas and the efficiency of vehicles operating on the roadway by using more energy-efficient design standards. Examples of techniques which may be used for fuel conservation through improved traffic flow in urban areas include roadway and street planning, so that traffic can flow at a constant and possibly optimum speed for maximum fuel economy, and land use planning along with an adequate street system to minimize trip distances. Examples of highway design standards which may be altered to increase the fuel economy of vehicles operating on the roadway are reduced surface roughness standards, and changes to vertical

TABLE 7 - EXAMPLES OF PERCENT FUEL SAVINGS RESULTING FROM TECHNOLOGICAL IMPROVEMENTS IN PASSENGER AND CARGO VEHICLES

Means	Vehicle	
	Passenger Cars	Trucks
(1) Aerodynamics	0.0-5.0[a]	0.0-5.0[d]
(2) Fuel System Modifications	5.0-6.0[b]	
(3) Minor Motor Modifications	9-16[b]	3-10[d]
(4) Gears	0.0-7.7[a]	0- 5[d]
(5) Weight	*	
(6) Radial Tires	0.0[b]	0.0-10[d]
(7) Combination of 1 and 4	15[a]	

* Substantial, but no estimate given (Note c).

a. Carr, G. W., et.al., Vehicle Fuel Economy: Effect of Aerodynamics and Gearing, Motor Industry Research Association, Great Britain, February, 1976.

b. Aerospace Corporation, Highway Vehicle Retrofit Evaluation, Phase I, Analysis and Preliminary Evaluation of Results, US Dept. of Commerce, NTIS, PB252554, November 1975.

c. Cunningham, G., Kapadia, R., Hudson, W.R., Summary of Current Information Available on Fuel Consumption, Tech. Memo., The University of Texas at Austin, June 1976.

d. Jack Fawcett Assoc , Truck Fleet Experience with Fuel Economy Improvement Measures, Submitted to the Federal Energy Administration, Washington D.C., June 1976.

TABLE 8 - EXAMPLES OF COST EFFECTIVENESS OF VEHICLE IMPROVEMENTS IN THE UNITED STATES (Ref. 3)

Option	Fuel Saving as Percent of Direct Transportation Energy		Likelyhood of Achievements
	1980	1990	
PASSENGER CAR Modest Modification to Passenger Car Motors	8.2	15.0	High
Advanced Technology	8.7	29.4	Medium to High
Advanced Technology and shift to smaller cars	13.3	32.0	Medium to High
Radial Tires	0.5	0.0	High
TRUCK Vehicle Efficiency	3.3	8.7	High

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