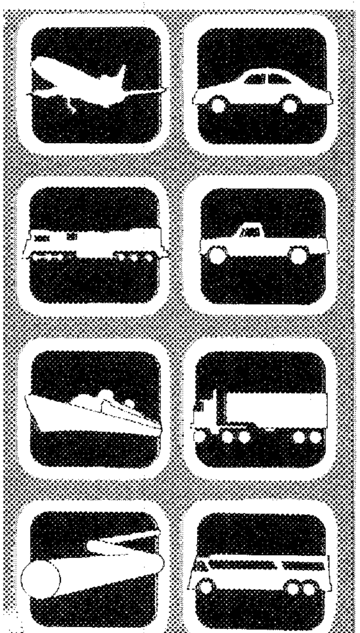
ORNL/TM-6450

Light Truck Forecasts

G. E. Liepins

TRANSPORTATION ENERGY PROGRAM: MONOGRAPH SERIES



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LIGHT TRUCK FORECASTS

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Regional and Urban Studies Section
Energy Division

Prepared for
Data Analysis Branch
Nonhighway Transport Systems and Special Projects
Transportation Programs
Office of Conservation and Solar Applications
Department of Energy

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HIGHLIGHTS

The recent dramatic increase in the number of light trucks (109% between 1963 and 1974) has prompted concern about the energy consequences of the growing popularity of the light truck. An estimate of the future number of light trucks is considered to be a reasonable first step in assessing the energy impact of these vehicles. This monograph contains forecasts based on two models and six scenarios. The coefficients for the models have been derived by ordinary least squares regression of national level time series data. The first model is a two stage model: The first stage estimates the number of light trucks and cars (together), and the second stage applies a share's submodel to determine the number of light trucks. The second model is a simultaneous equation model. The two models track one another remarkably well, within about 2%. The scenarios were chosen to be consistent with those used in the Lindsey-Kaufman study *Projection of Light Truck Population to Year 2025*. Except in the case of the most dismal economic scenario, the number of light trucks is expected to increase from the 1974 level of 0.09 light truck per person to about 0.12 light truck per person in 1995.

ACKNOWLEDGMENTS

I wish to express my appreciation of the people who contributed to this work: Phil Patterson for requesting the study, Steve Corey who assisted in the programming, Steve Cohn for lively discussions of appropriate models, and David Greene and John Trimble for their valuable comments.

SUMMARY OF FINDINGS

According to the Truck Inventory and Use Survey, in 1972, 14.598×10^6 light trucks were registered in the United States. By 1995, that number is expected to increase to about 30×10^6 for the scenario considered most likely by Lindsey-Kaufman,[1] Case IIA. Except in the case of the most dismal economic scenario, the number of light trucks is expected to increase not only in numerical count, but also in terms of light truck per person ratios as well as light truck per car ratios. The 1972 light truck per person ratio was 0.075, and is predicted to be 0.12-0.13 by 1995 (Case IIA). The light truck per car ratio, which was 0.16 in 1972, is forecast to be 0.20 in 1995. Under future economic and technological conditions not drastically different from the present, the general agreement is that the number of light trucks will increase. It is also a matter of general concensus that the rate of growth in the light truck per person ratio will ultimately slow; only the timing and the magnitude of the slowing is in debate.

Theoretically, inventories of light trucks depend on at least two types of factors: First, economic and population factors, and second, consumer tastes (because, to a degree, light trucks are substitutes for cars). Because of the inavailabity of appropriate data, the latter factor (consumer tastes) has not been explicitly captured in the formulation of these models. The models are driven primarily by personal disposable income and population; each has a significant positive influence on the number of vehicles, cars, and light trucks. Household size appears with a negative coefficient as an explanatory variable for the number of vehicles — a reasonable finding in that members of the same household are probably more likely to share the use of a vehicle than persons from different households. Unemployment also enters the vehicle equation with a negative coefficient. The remaining explanatory variable, age distribution between 15 and 45, expressed as a percentage, enters significantly with a positive coefficient in each of the regression equations. Age distribution is discussed in greater detail in the section of this monograph devoted to technical analysis.

1. INTRODUCTION

The purpose of this monograph is to provide forecasts under various economic conditions from 1975 through 2000 of the number of light trucks (i.e., trucks weighing less than or equal to 10,000 lb) registered in the continental United States. Light trucks have become a concern of the Transportation Programs Division of the Office of Conservation and Solar Applications, Department of Energy, because of the rapid increase in their numbers: the inventory of light trucks increased 109% from 1963 through 1974,[2-5] while that of cars increased only 52% for the same period.

Sales statistics demonstrate this explosive growth more clearly. Sales of light trucks increased from 0.934×10^6 in 1963 to 2.256×10^6 in 1974, with a high of 2.556×10^6 in 1973. For the same years, car sales were 7.941×10^6, 8.852×10^6, and 11.430×10^6 respectively.[6] Data indicate that in 1963, the ratio of light trucks to cars sold was approximately 1:8.5, whereas in 1974 the ratio was 1:4. Even more dramatic is the fact that the Chevrolet Division of General Motors now sells one light truck for every 1.8 cars. The ratio in 1960 was one truck for every 6.3 cars.[7] To be sure, the numerical increase in the number of trucks (9.7×10^6) is small in comparison to that of cars (36.2×10^6), yet if the growth of the number of light trucks continues at the present rate, light trucks could become a major factor in petroleum product consumption. This trend is further aggravated by the fact that light trucks historically have had poorer fuel economy than automobiles. (Estimates of intercity fuel economy for automobiles were 13.0 mpg in 1972 for luxury automobiles; 18.0 mpg for standard, 22.5 mpg for compact, and 30.0 mpg for subcompact,[8] as opposed to 10.8-12.4 mpg for light trucks.[9]

This monograph provides forecasts for the number of light trucks under various economic conditions in the years 1975 through 2000.[10] The projections are based on six scenarios: Cases I, II, IIA, III, and IV are those assumed by the Lindsey-Kaufman study.[1] Case "Hirst Data" is based on projections by E. Hirst of Oak Ridge National Laboratory.[10]

The estimates in this study are the expected values generated for each scenario and, at best, are presumed to have validity only under socioeconomic-technological conditions not drastically different from the present.

This monograph presents data generated by the two models, a discussion of the technical details of the models, and finally, conclusions.

Below are the projections derived from use of the models in conjunction with the scenarios considered. Figures 1.1 to 1.6 present the projections graphically, Tables 1.1 and 1.2 list the projected numbers of light trucks for selected years, and Table 1.3 lists the parameter values for each scenario.

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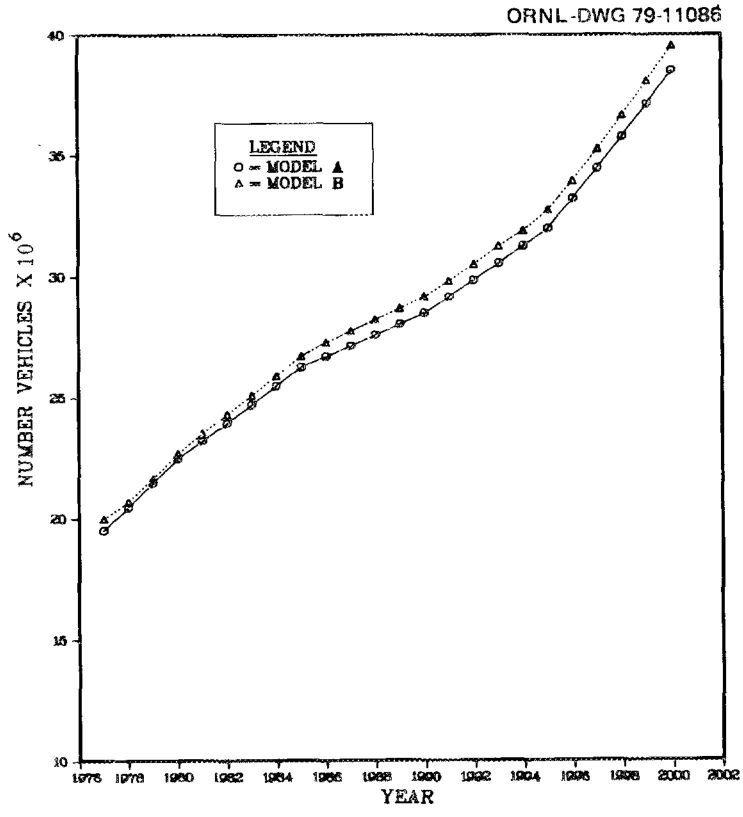

Fig. 1.1. Light Truck Forecast — Case I.

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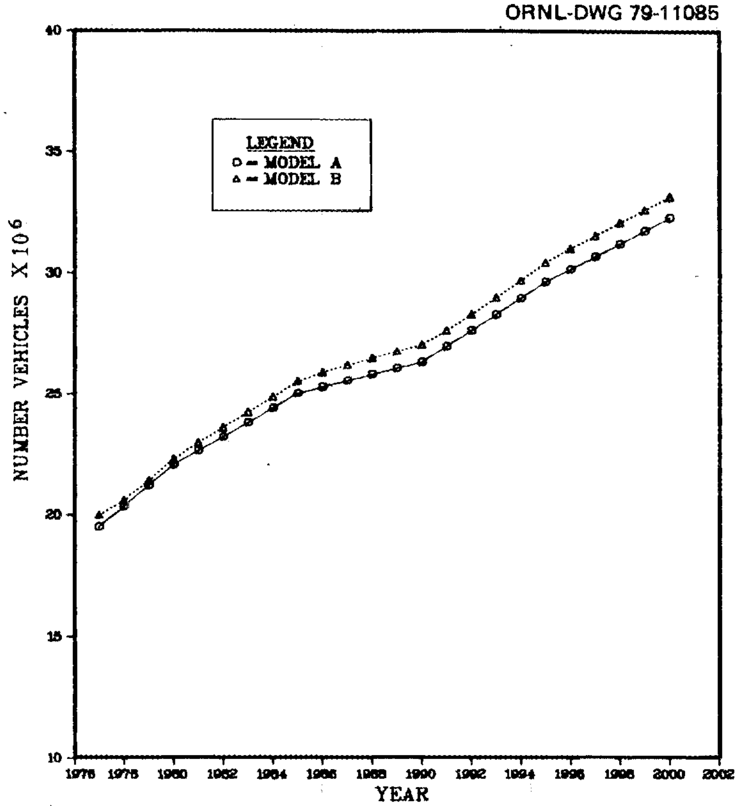

Fig. 1.2. Light Truck Forecast — Case II.

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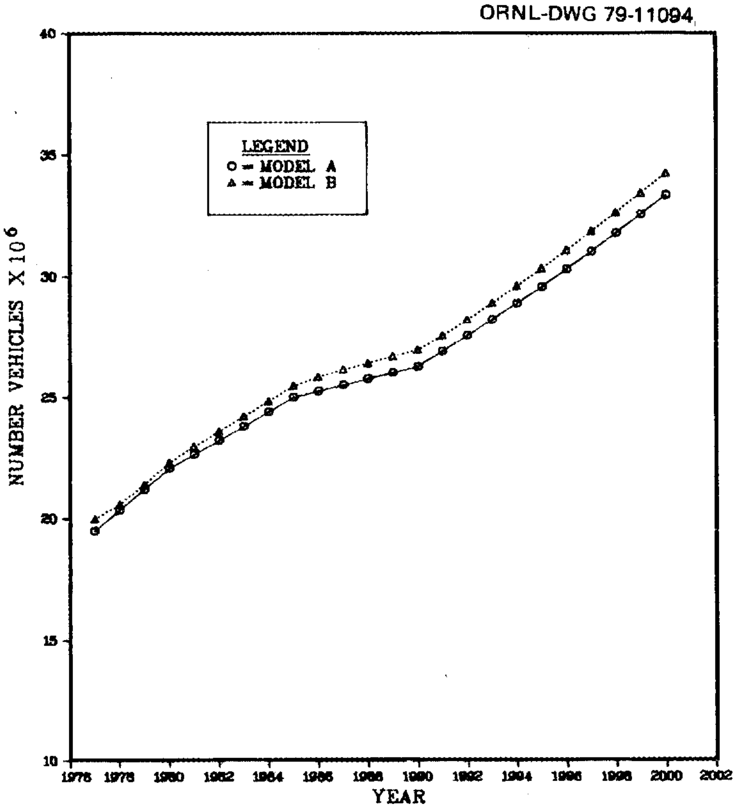

Fig. 1.3. Light Truck Forecast — Case IIA.

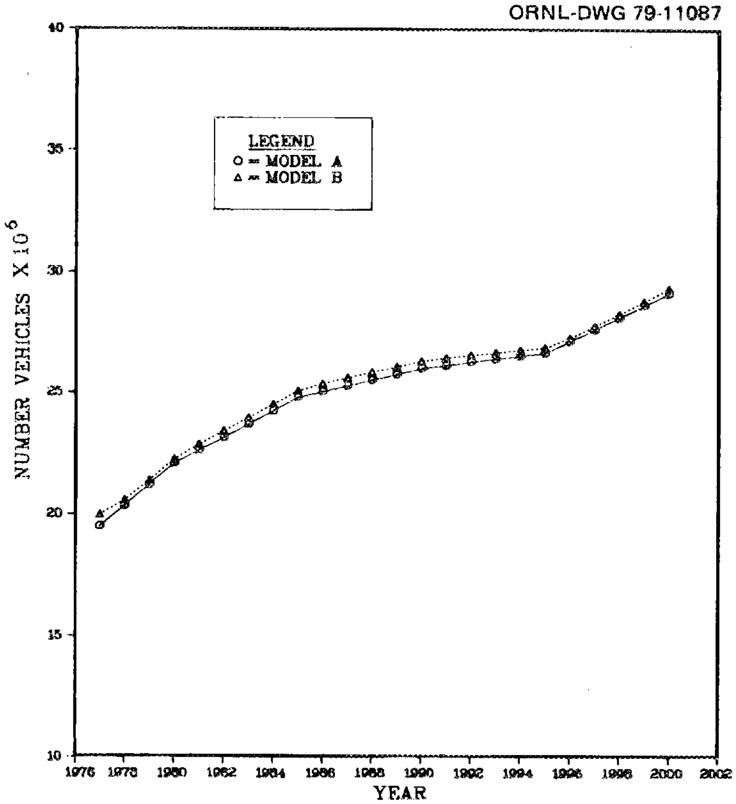

Fig. 1.4. Light Truck Forecast — Case III.

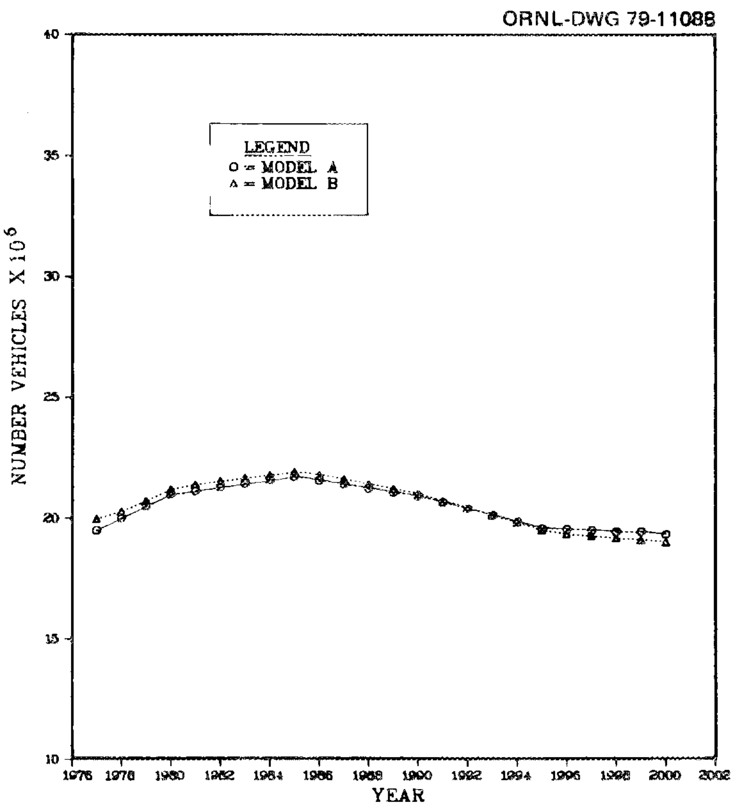

Fig. 1.5. Light Truck Forecast — Case IV.

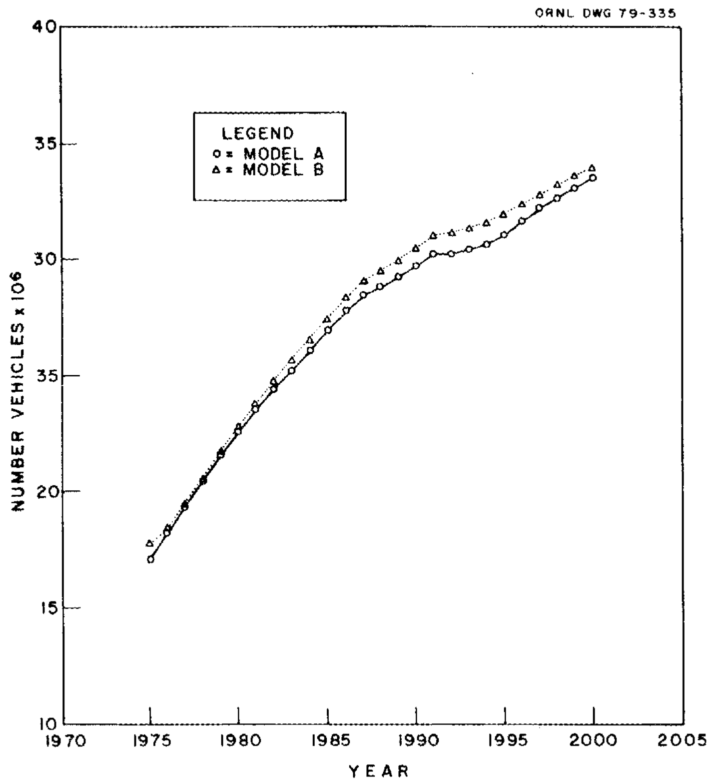

Fig. 1.6. Light Truck Forecast — Hirst Data.

Table 1.1. Total Count of Light Trucks × 10^3

	Truck Inventory and Use Survey						
Case	1963	1967	1972	Model	1975	1995	2000
I				A	18,962	32,894	36,286
				B	19,240	33,487	36,719
II				A	18,962	30,120	31,888
				B	19,240	30,773	32,466
IIA				A	18,962	29,396	32,466
				B	19,240	30,164	32,784
III				A	18,962	27,570	28,218
	8,853	11,318	14,598	B	19,240	27,603	27,962
IV				A	18,962	18,673	19,444
				B	19,240	18,181	18,619
Hirst Data				A	17,091	31,057	33,509
				B	17,762	31,992	34,021

Table 1.2. Percent Distribution of Light Trucks by Major Use

Truck Inventory and Use Survey				Projections		
Major use	1963	1967	1972	1975	1995	2000
Personal	34.7	44.8	53.4	56.1	59.3	60.8
For hire	1.3	0.6	0.6	0.6	0.6	0.5
Services and utilities	9.0	8.5	10.2	10.4	9.8	9.4
Wholesale and retail	10.4	8.5	6.1	6.3	5.9	5.6
Manufacturing and mining	2.7	1.7	1.5	1.5	1.4	1.4
Construction	9.7	8.3	6.9	6.8	6.2	5.9
Agriculture	29.6	23.6	20.1	20.1	18.6	18.0
Forestry and lumber	1.0	1.0	0.5	0.5	0.5	0.5
Other	1.6	3.6	1.2	1.2	1.2	1.2

Table 1.3. Parameters for scenarios

	1975	Case I 1995	Case I 2025	Case II 1995	Case II 2025	Case IIA 1995	Case IIA 2025
GNP[a]	1202.1	2620.35	8420.5	2358.9	3522.6	2208.5	4159.0
POP[b]	213.54	266.6	369.3	240.0	280.0	240.6	287.2
PDI[c]	3146	5459.1	12779.2	5459.1	7242.6	5413.6	8639.4
HC[d]	166.8	346.9	1040.5	346.9	1040.5	346.9	1040.5
UNEMP[e]	8.5	5.0	5.0	6.5	5.0	6.5	5.0

	1975	Case I 1980	Case I 1985	Case I 1990	Case I 2000	Case II 1980	Case II 1985	Case II 1990	Case II 2000	Case IIA 1980	Case IIA 1985	Case IIA 1990	Case IIA 2000
AGE[f]	44.0	44.06	43.95	42.34	40.65	44.06	43.95	42.34	42.07	44.06	43.95	42.34	42.07

	1975	Case III 1995	Case III 2025	Case IV 1995	Case IV 2025	Hirst Data 1995	Hirst Data 2025
GNP	1202.1	1757.2	3707.6	1231.3	1983.8	2486.1	2981.3
POP	213.54	251.1	294.7	240.9	252.3	254.495	260.378
PDI	3146	4016.7	7242.6	2853.6	3411.9	5155	5832.5
HC	166.8	346.9	1040.5	346.9	1040.5	346.9	1040.5
UNEMP	8.5	5.0	5.0	11.0	11.0	7.29	7.29

	1975	Case III 1980	Case III 1985	Case III 1990	Case III 2000	Case IV 1980	Case IV 1985	Case IV 1990	Case IV 2000	Hirst Data 1980	Hirst Data 1985	Hirst Data 1990	Hirst Data 2000
AGE	44.0	44.64	45.30	44.52	42.07	44.64	45.30	44.52	42.07	44.68	45.47	44.73	41.77

[a]GNP (gross national product) is given in 10^9 1972 dollars.

[b]POP (population) is given in 10^6 people.

[c]PDI (personal disposable income) is given in 1967 dollars.

[d]HC (consumer price index for housing) is given in 1967 dollars and is extrapolated from historical data on basis of average growth for the period 1963-1975.

[e]UNEMP (unemployment) is given as percentage of unemployment for all workers.

[f]AGE is the percent of population between the ages of 15 and 45; i.e., $15 < x < 45$.

Sources: Unemployment data — David Curry, et al., *Transportation in America's Future: Potential for the Next Half Century,* prepared by Standford Research Institute for the U.S. Department of Transportation, DOT-TPI-20-77-21, June 1977; Age data — *Statistical Abstracts of the United States, 1977,* U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1977; Lindsey-Kaufman Co., *Projection of Light Truck Population to Year 2025,* ORNL/Sub-78/14285/1, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1978; R. H. Goshorn, *Socio-Economic Factors Affecting Household Formation and Housing Size in the United States,* Oak Ridge National Laboratory, December 1977. (Computer print-out made available by E. Hirst of ORNL.)

2. DISCUSSION OF THE ORNL FORECASTS

The forecasts are based on two models: A and B. Model A first estimates the number of light trucks and cars together and then applies a share's submodel to generate the forecast of light trucks. (The reasoning behind this approach is that light trucks can be considered as substitutes for cars.) Model B estimates the number of cars and light trucks separately and yields the number of vehicles as a sum of the estimates. The forecasts generated by these two models (based on the scenarios detailed in Table 1.3) are remarkably close. With the exception of the latter years in Case IV, the difference between the two models rarely exceeds 2%.

The model forecasts of light truck inventories are considerably lower than those of certain industry experts, the Lindsey-Kaufman Company in particular. Unfortunately, the derivation of Lindsey-Kaufman forecasts is not sufficiently quantitative to determine the source of the discrepancy. One can only surmise that the discrepancy is primarily due to a subjective evaluation of future and present societal attitudes as they affect the purchase of light trucks (other than the degree to which they are reflected in the other variables, these attitudes are implicitly assumed to remain invariant in the models because there is no explanatory variable which explicitly captures them).

The most dramatic differences between the models and Lindsey-Kaufman forecasts in the growth rate of light trucks manifest themselves in the years 1975-1980.

	Light trucks $\times 10^3$ (in 1980)		
	Model A	Model B	L-K
Case I	22,477	22,873	29,500[a]
Case II	21,876	22,280	28,000[a]
Case IIA	21,843	22,245	28,000[a]
Case III	21,558	21,864	28,000[a]
Case IV	19,379	19,684	26,000[a]
Hirst Data	22,583	22,834	

[a]Read from graph.

The economic forecasts in the Lindsey-Kaufman (L-K) study do not appear of themselves to be sufficient justification for the explosive light truck growth forecasted by L-K. If such growth does occur, it must be attributed to shifts in consumer preference which had not totally manifested themselves by 1976. [The number of light trucks ($20,163 \times 10^3$) calculated on the basis of a light truck to all truck ratio of 0.74 to 1.0, and total truck estimate of $27,130 \times 10^3$ by the Motor Vehicle Manufacturers Association[5] is close to the model projections documented herein.]

The plausibility of the forecasts generated by the models can further be evaluated on several grounds.

1. Models A and B showed surprising consistency with one another.

2. The Federal Highway Administration has forecast the car per person ratio to be 0.54 car per person in 1990. Cases I, II, IIA, and III yield ratios in the range from 0.549 car per person to 0.561 car per person for 1990. (To be sure, Case IV forecasts about 0.47 car per person, but this is not surprising in view of the dismal economic scenario applied in this case.) The Hirst Data yield a ratio of 0.572.

3. In terms of historical trends, one would expect a car sales per truck sales ratio between 9:1 and 3:1, probably somewhat toward the lower end. The forecasts generated by the ORNL models are not inconsistent with these expectations. Again, Case IV is the most aberrant.

If one assumes the 1961 to 1974 average implicit retirement rates of 0.074 and 0.051 for cars and trucks respectively, use of the equations

$$\text{car sales (1975 through 2000)} = \sum_{i=1975}^{1999} [C(i + 1) - C(i) + 0.074C(i)] ,$$

$$\text{truck sales (1975 through 2000)} = \sum_{i=1975}^{1999} [T(i + 1) - T(i) + 0.051\, T(i)] ,$$

where

C(i) = car inventory in year i,

T(i) = light truck inventory in year i,

results in the cumulative car sales per truck sales ratios (1975-2000) found in columns 2 and 3 of the table below. The rates 0.069 and 0.059 yield the ratios in the last two columns.

	Car sales per truck sales ratio[a]			
	Retirement rates 0.074, 0.051[b]		Retirement rates 0.069, 0.059[c]	
	Model A	Model B	Model A	Model B
Case I	5.85	5.82	5.01	4.96
Case II	5.93	6.12	5.02	5.17
Case IIA	5.89	5.85	4.99	4.94
Case III	6.73	6.71	5.66	5.60
Case IV	8.61	9.00	6.99	7.24
Hirst Data	5.76	5.71	4.92	4.87

[a]Estimates are highly dependent on the assumed retirement rate. For example, an equal retirement rate for both cars and trucks yields a car sales per truck sales ratio of 4.5:1 for Case I, model A.

[b]Average implicit retirement rates for 1961 to 1974.

[c]Average implicit retirement rates for 1970 to 1976.

	Retirement rates	
Year	Light trucks	Cars
1964	0.035	0.070
1965	0.049	0.089
1966	0.057	0.089
1967	0.052	0.068
1968	0.059	0.079
1969	0.066	0.085
1970	0.047	0.059
1971	0.041	0.065
1972	0.038	0.063
1973	0.070	0.078
1974	0.088	0.084
1975	0.076	0.067
1976	0.056	

On the basis of the car sales per truck sales ratios calculated above and shown in the tables below, one might suspect that the models underestimate somewhat the number of light trucks for the short run and that the L-K projections overestimate this number.

Year	Car sales per truck sales ratio
1963	8.502
1964	7.923
1965	7.995
1966	7.159
1967	7.208
1968	6.811
1969	6.382
1970	6.063
1971	6.161
1972	5.214
1973	4.467
1974	3.924
1975	4.104
1976	3.707

Car sales per truck sales ratio	Implicit inventory of light trucks in 1980 at 6% annual retirement rate (10^3)*
1:1	53.82
1.5:1	41.08
2.0:1	34.72
2.5:1	30.90
3.0:1	28.35
3.5:1	26.53
4.0:1	25.17
4.5:1	24.11
5.0:1	23.26

Car inventory forecasts of model B (Case I) and car retirement rates of 7% annually.

Clearly use of the minimum 1963-1976 car sales per truck sales ratio would result in an estimate of about 25-26 × 10^6 light trucks in 1980. An estimate more consistent with 1974-1976 trends would seem to be 24-25 × 10^6 light trucks.*

4. Another means of evaluating the plausibility of the forecasts is to investigate the light truck per person ratio.

	Light truck per person ratio[a] (1995)		
	Model A	Model B	L-K
Case I	0.120	0.122	
Case II	0.123	0.126	0.16
Case IIA	0.122	0.126	0.14
Case III	0.126	0.109	
Case IV	0.077	0.075	
Hirst Data	0.123	0.127	

[a]Historically, this ratio has varied between 0.0450 and 0.0876 (1960 to 1974).

Year	Light truck per person ratio
1961	0.045
1962	0.047
1963	0.047
1964	0.052
1965	0.054
1966	0.057
1967	0.060
1968	0.062
1969	0.065
1970	0.068
1971	0.071
1972	0.075
1973	0.082
1974	0.088

*Case I is the scenario leading to the greatest number of both cars and trucks.

For 1995 (Case IIA), the "best judgment" of the L-K report, the models and the L-K forecast are reasonably close.

5. The percentage change in the inventory of light trucks for the years 1963-1976 is given in the following table.

Year	Change in light truck inventory (%)
1963-1964	6.4
1964-1965	7.0
1965-1966	6.3
1966-1967	5.8
1967-1968	4.9
1968-1969	5.6
1969-1970	5.3
1970-1971	5.8
1971-1972	7.3
1972-1973	9.2
1973-1974	6.1
1974-1975	4.8
1975-1976	5.4

If one assumes 20.0×10^6 light trucks in 1976, then according to what one believes to be a reasonable annual percentage change in the stock of light trucks, one arrives at the 1980 inventory projections as listed below; and again, reasonable estimates would seem to be between 24 and 26×10^6 light trucks.

Annual change in inventory (%)	1980 inventory of light trucks (10^6)
4.0	23.40
4.5	23.85
5.0	24.31
5.5	24.78
6.0	25.25
6.5	25.79
7.0	26.22
7.5	26.71
8.0	27.21
8.5	27.72
9.0	28.23
9.5	28.75
10.0	29.28

In short, if light truck sales continue to increase at or somewhat above their historical maximum rate, a projected inventory of light trucks for 1980 would be about 28×10^6. A projected inventory of about 24×10^6 is in keeping with a more modest rate of growth, for instance, as realized in the period 1974-1976. Thus, the projections determined by the models may be conservative in the sense that the models were calibrated with data for the period 1963-1974. However, for the long term, it is difficult to determine whether the light truck market will sustain its recent high rate of growth or will level off.

The weakest point of the analysis is perhaps the partition of the total number of light trucks into major use categories. The algorithm to achieve this end was particularly simple: the 1972 partition was extrapolated on the basis of Table 34, p. 50 of *Trucking Activity and Fuel Consumption* (Table 2.1 of this report). The specific equations are given in the next section along with a more detailed justification. On the basis of cross-sectional state level data for 1972, the extrapolation scheme does seem unreasonable if one assumes the forecasts listed in Table 2.1.

Of course, any forecast generated by a formal model depends on the conjectured scenario which drives the model. For this monograph, six such scenarios were selected and are detailed in Table 1.3. For Cases I, II, IIA, III, and IV, the data for GNP, POP, and PDI have been taken directly from the L-K document (GNP deflated to 1972 dollars, PD deflated to 1967 dollars). The unemployment statistics were determined from Curry et al.,[11] and the AGE statistics were taken from the Statistical Abstract[12] for the appropriate Census Bureau projections as detailed in L-K. The variable HC has been determined to grow at 3.7% per annum. The scenario "Hirst Data" is based on projections by Hirst.[10]

The variables GNP, POP, PDI, and HC were interpolated in terms of constant growth for the periods 1975 to 1995, and 1995 to 2025; the variables UNEMP and AGE were interpolated linearly.

Table 2.1. Growth Rates of GNP and Sector Outputs Used in the Trucking Projections

	Average annual rate of growth		
	1972-1980	1980-1990[a]	1972-1990
Gross national product[b]	3.1	2.9	3.0
Agriculture[c]	3.3	2.5	2.9
Construction[c]	2.5	2.5	2.5
Manufacturing and mining[c]	3.5	3.2	3.3
Wholesale and retail trade[c]	4.1	2.4	3.1
Services and utilities[c]	3.8	2.7	3.2
For hire trucking[d]	3.1	2.9	3.0
Personal trucking[d]	4.9	4.0	4.4

[a]The projected growth rates applied in this study are the same for 1980-1985 and 1985-1990.

[b]These growth rates are from the Data Resources Incorporated (DRI) economic projections provided Jack Faucett Associates by FEA.

[c]These growth rates are from the University of Maryland Input-Output projections adjusted to be compatible with the DRI GNP growth.

[d]These growth rates are the result of special analyses made by Jack Faucett Associates.

Source: Jack Faucett Associates, Inc., *Trucking Activity and Fuel Consumption, 1973, 1980, 1985, and 1990*, Chevy Chase, Md., July 1976, Table 34, p. 50.

3. TECHNICAL ANALYSIS OF MODELS

Two difficulties common to much of econometric analysis are immediately encountered in this attempt to forecast the number of light trucks. The first is that most economic indicators, as well as the number of light trucks, have historically exhibited steady growth and, therefore, simulation forecasts are apt to diverge from a heuristically feasible region. The second is that data are not available for the conventional explanatory variable — average light truck price — nor for a time series for light truck fuel economy. The results presented in this paper must be interpreted in light of these difficulties.

The first difficulty, that of predictions exceeding heuristically reasonable bounds, was dealt with by choosing a logistic formulation for each of the models, a formulation which assures that the sum of light trucks and cars not exceed the population:

MODEL A

Stage 1: $$\text{LNVEH} = \ln\left(\frac{\text{VEH/POP}}{1 - \text{VEH/POP}}\right) = f(\text{PDI, HHSZ, UNEMP, AGE, FP, } \ldots) ,$$

Stage 2: $$\text{LSTSC} = \ln(\text{T/C}) = g(\text{PDI, HHSZ, UNEMP, AGE, FP, } \ldots) ,$$

Stage 3: $$\frac{\text{T + C}}{\text{VEH}} = 1$$

$$\text{T} = \{[g(\text{PDI, } \ldots)]/[1 + g(\text{PDI, } \ldots)]\} \times \text{VEH} .$$

The first stage of this model regresses a transformation of the sum of the number of light trucks and cars against the explanatory variables. The second stage develops the shares model, and the third stage uses the relationship T + C = VEH and the results of the first two stages to calculate the number of light trucks.

In the estimation of the shares model, it would be desirable as well as conventional to include the ratio of prices (truck price to car price); however, all truck prices known to the author appear in disaggregated form in *Automotive News*, and the aggregation of these data was beyond the scope of this study. Similarly, light truck fuel economy appears not to be available in a time series, so that neither of these explanatory variables was used.

As mentioned previously, the implicit constraint in model A is that the sum of light trucks and cars not exceed the population. Though this may appear to be an artificial constraint, the fact that the ratio VEH/POP stays well away from the asymptotic limit 1 in all the simulations indicates that the constraint has not been fully activated and is less artificial than may appear at first glance.

The second model, model B, depends on a similar logistic formulation:

MODEL B

$$\text{LNTRVEH} = \ln\left[\frac{T/POP}{1 - (T + C)/POP}\right] = f(\text{PDI, HHSZ, UNEMP, AGE, FP, } \ldots) \; ,$$

$$\text{LNCVEH} = \ln\left[\frac{C/POP}{1 - (T + C)/POP}\right] = G(\text{PDI, HHSZ,UNEMP, AGE, FP, } \ldots) \; .$$

This simultaneous system of equations can easily be solved for both T and C. Moreover, it is easily seen (as long as $T,C > 0$) that model B constrains T to be asymptotically smaller than would be determined by the formulation

$$\ln\left(\frac{T/POP}{1 - T/POP}\right) \; .$$

Model B is formulated as a stock adjustment model, which is actually equivalent to a first-order autoregressive model. The heuristics for such a model are outlined below.

One first assumes that the economically stable equilibrium of LNTRVEH*(n) at time n is given in terms of other explanatory variables,

$$\text{LNTRVEH}^*(n) = f(\text{PDI, HHSZ } \ldots) \; . \qquad (1)$$

The number of light trucks, being a major durable capital good, cannot be expected to immediately adjust to equal the theoretical equilibrium; hence an adjustment process is postulated,

$$\text{LNTRVEH}(n) = \text{LNTRVEH}(n - 1) + \delta[\text{LNTRVEH}^*(n) - \text{LNTRVEH}(n - 1)] \ . \qquad (2)$$

Of course, one expects that the adjustment coefficient δ lies between 0 and 1 (i.e., $0 < \delta < 1$). The simultaneous solution of Eqs. (1) and (2) yields

$$\text{LNTRVEH}(n) = (1 - \delta)\text{LNTRVEH}(n - 1) + \delta\ [f(\text{PDI}, \text{HHSZ}, \ldots)] \ .$$

The smaller the regression coefficient accompanying the lagged variable, the more rapid the implicit adjustment response.

The actual equations of models A and B are given below. The coefficients were estimated by ordinary least squares regression of national time series data. (The significance levels of the coefficients are included in parentheses.)

MODEL A

1. $$\text{LNVEH} = \underset{(0.0001)}{-18.60887239} + \underset{(0.0001)}{3.31754182}\text{LAGE} - \underset{(0.1077)}{0.56344654}\text{LHHSZ}$$

$$+ \underset{(0.0001)}{0.88412928}\text{LPDI} - \underset{(0.0244)}{0.04234495}\text{LUNEMP} \ ,$$

$$R^2 = 0.9995 \ , \quad \text{DW} = 1.5073 \ .$$

2. $$\text{LSTSC} = \underset{(0.0001)}{-9.76902093} + \underset{(0.0003)}{1.13262720}\text{LAGE} + \underset{(0.0001)}{0.46539166}\text{LPDI} \ ,$$

$$R^2 = 0.9850 \ , \quad \text{DW} = 2.0244 \ .$$

MODEL B

1. $LNCVEH = -14.74195127 + 2.36651560 LAGE + 0.74045065 LPDI$
(0.0003) (0.0004) (0.0004)

$+ 0.27920896 LNCVEH1$,
(0.0818)

$R^2 = 0.9991$, $DW = 1.8839$.

2. $LNTRVEH = -22.49405332 + 3.29024808 LAGE + 1.11105327 LPDI$
(0.0001) (0.0002) (0.0002)

$+ 0.25989339 LNTRVEH1$,
(0.0708)

$R^2 = 0.9988$, $DW = 2.5365$.

The residuals of models A and B are examined below.

MODEL A

Eq. 1. The DW statistic is inconclusive.[13] The runs test[14] did not indicate a significant correlation among the residuals [6 runs with a signs distribution of (6,8)].*

Eq. 2. The DW statistic indicates lack of first order autocorrelation. The runs test [7 runs with a sign distribution of (5,9)] did not indicate a significant correlation among the residuals.

MODEL B

Eq. 1. The runs test [7 runs with a sign distribution of (6,8)] did not indicate a significant correlation among the residuals. The Durbin K_2 statistic[15] is 0.0505 — inconclusive.

Eq. 2. The runs test [7 runs with a sign distribution of (6,8)] did not indicate a significant correlation among the residuals. The Durbin K_2 statistic is 1.0088 — no significant correlation implied.

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*The runs test counts the number of sign changes in the residuals and adds one. Thus, if the residuals had signs +, -, -, +, +, -; the runs tests would be applied to 4 runs with a signs distribution of (2,2).

The variables are defined as follows:

$$LNVEH = \ln\left(\frac{VEH/POP}{1 - VEH/POP}\right) ;$$

$VEH = T + C;$

$T =$ light trucks;

$C =$ cars;

$POP =$ population;

$LSTSC = \ln(T/C);$

$LAGE = \ln(\%$ of population between the ages of 15 and 45 — i.e., $15 < x < 45);$

$LPDI = \ln($personal disposable income$);$

$LUNEMP = \ln(\%$ unemployment$);$

$$LNCVEH = \ln\left(\frac{C/POP}{1 - VEH/POP}\right);$$

$LNCVEH1 =$ LNCVEH lagged by one period, i.e., $LNCVEH(n-1) = LNCVEH1(n);$

$$LNTRVEH = \ln\left(\frac{T/POP}{1 - VEH/POP}\right);$$

$LNTRVEH1 =$ LNTRVEH lagged by one period.

The following additional variables were considered as potential explanatory variables:

- gross national product
- average vehicle-miles per car
- average vehicle-miles per truck
- number of licensed drivers
- car fuel economy
- price of new cars
- price of gasoline
- retail-wholesale sales
- car sales
- light truck sales
- construction activity

Probably, the least intuitive of the explanatory variables is LAGE. This variable was chosen for inclusion as an explanatory variable because it was suspected that the ownership rate of vehicles by persons in this age bracket was higher than that by persons in other age brackets. The available data were insufficient to either confirm or refute this conjecture, and it is conceivable that the resultant correlation is spurious. However, when the variable LAGE was replaced by the natural logarithm of the percentage of the population between the ages of 15 and 65, the explanatory variable lost its significance, even though the population in the 15 to 65 age bracket was monotonically increasing during this period (both numerically and relatively).

Since the L-K scenarios did not specify household size, an additional regression was run:

$$\underset{}{LNHHSZ} = \underset{(0.0001)}{-2.47111848} + \underset{(0.0001)}{0.64867304LHC} - \underset{(0.1047)}{0.03117339LUNEMP} \; ;$$

$$R^2 = 0.9877 \; , \quad DW = 1.9561 \; .$$

Runs test: 8 runs, sign distribution (7,7) — no significant correlation implied.

The variables are defined to be

$$LNHHSZ = \ln\left(\frac{HSE/POP}{0.5 - HSE/POP}\right) \; ,$$

$$HSE = \text{number of households} \; ,$$

$$LHC = \ln(\text{housing cost index}) \; .$$

The application of this equation to the simulation scenarios resulted in predicted household size of 2.62 to 2.64 for 1990, consistent with Census Bureau predictions of 2.68 for forecast A, 2.60 for forecast B, and 2.61 for forecast C. A consistent interpretation of the regression equation could be that unemployment increases short-term household size by causing more people to share expenses, and that increased housing costs result in long-term reductions of family size.

To partition the total number of light trucks into major use categories, the growth rates for the respective sectors (which determined use) were applied to the 1972 distribution of light trucks and the subsequent results were normalized. This algorithm was later tested against 1972 cross sectional data with reasonable results. The test consisted of forming all two-fold combinations (pairs) of states and, for each combination, estimating the percentage of light trucks used primarily for retail-wholesale trade in the second state on the basis of both states' retail sales, construction contracts, and the relative number of light trucks used for both construction or retail-wholesale trade in the first state. Formally, let

C(i) = construction contracts in state i,
r(i) = retail sales in state i,
LC(i) = light trucks used in construction state i,
Lr(i) = light trucks used in retail-wholesale trade state i.

If the proportion of each type of light truck is calculated as

$$nLC(i) = LC(i)/[LC(i) + Lr(i)] ,$$

$$nLr(i) = Lr(i)/[LC(i) + Lr(i)] = 1 - nLC(i) ,$$

then the error of the extrapolation D(i,j) can be calculated as

$$D(i,j) = nLr(j) - \frac{nLr(i)[r(j)/r(i)]}{nLr(i)[r(j)/r(i)] + nLC(i)\ [C(j)/C(i)]} .$$

For i < j, the mean and standard deviation of the values D(i,j) were calculated:

$$\mu(D) = -0.00316 ,$$

$$\sigma(D) = 0.13307 .$$

For the observed values of nLr, the mean and standard deviation were determined to be

$$\mu(nLr) = 0.64880 ,$$

$$\sigma(nLr) = 0.09082 .$$

(Figures 3.1 and 3.2 show the frequency distribution of D and nLr with the same scale for the abscissa.)

Although the distribution of the error D has mean nearly zero, it is not as tightly concentrated as would be desirable. This suggests of course that though the partitioning of light trucks into major use categories is not unreasonable, it must be viewed with healthy caution.

The behavior and sensitivity to perturbations of the initial values and hypotheses of the models can be inferred by approximating these models by a linearized version. Consider the sequence of vectors {X(n), n = 0,1} defined by

$$X(n) = \begin{bmatrix} \text{LNTRVEH} & (n - 1) \\ \text{LNCVEH} & (n - 1) \\ \text{LNVEH} & (n) \\ \text{LSTSC} & (n) \\ \text{LHHSZ} & (n) \\ \text{LAGE} & (n) \\ \text{LPDI} & (n) \\ \text{LUNEMP} & (n) \end{bmatrix} = AX(n - 1) + B ,$$

with additional boundary conditions

$$X(0) = \begin{bmatrix} \text{LNTRVEH} & (-1) \\ \text{LNCVEH} & (-1) \\ \text{LNVEH} & (0) \\ \text{LSTSC} & (0) \\ \text{LHHSZ} & (0) \\ \text{LAGE} & (0) \\ \text{LPDI} & (0) \\ \text{LUNEMP} & (0) \end{bmatrix} ,$$

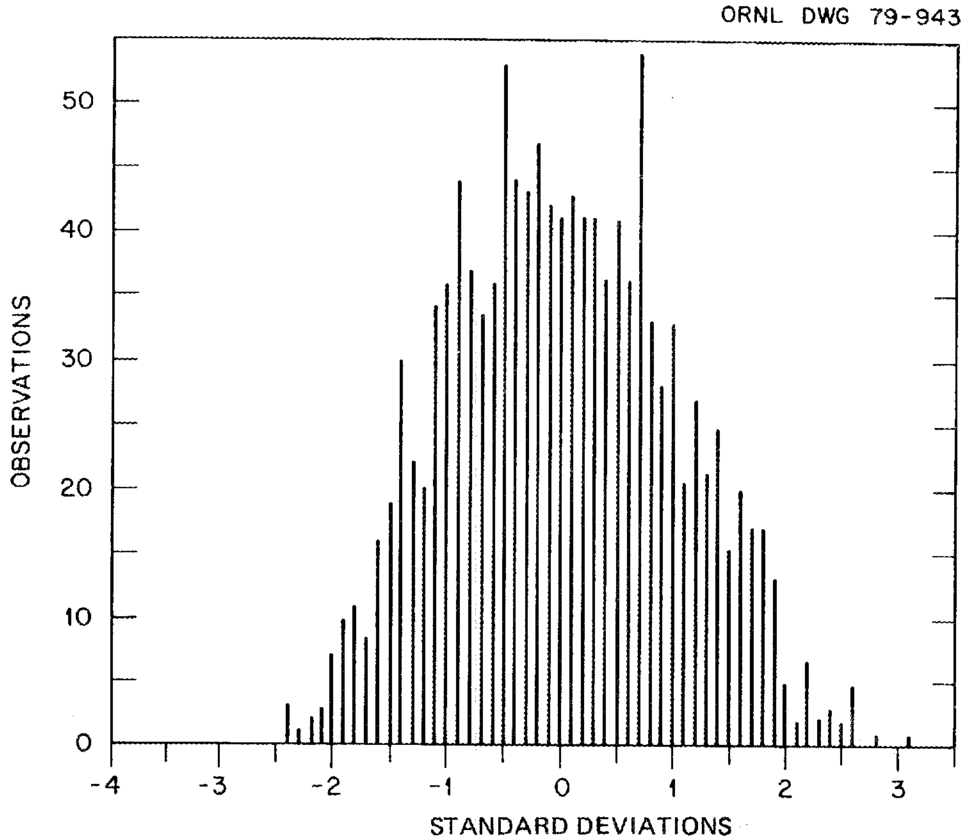

Fig. 3.1. Frequency Distribution of D(i,j) for 1972.

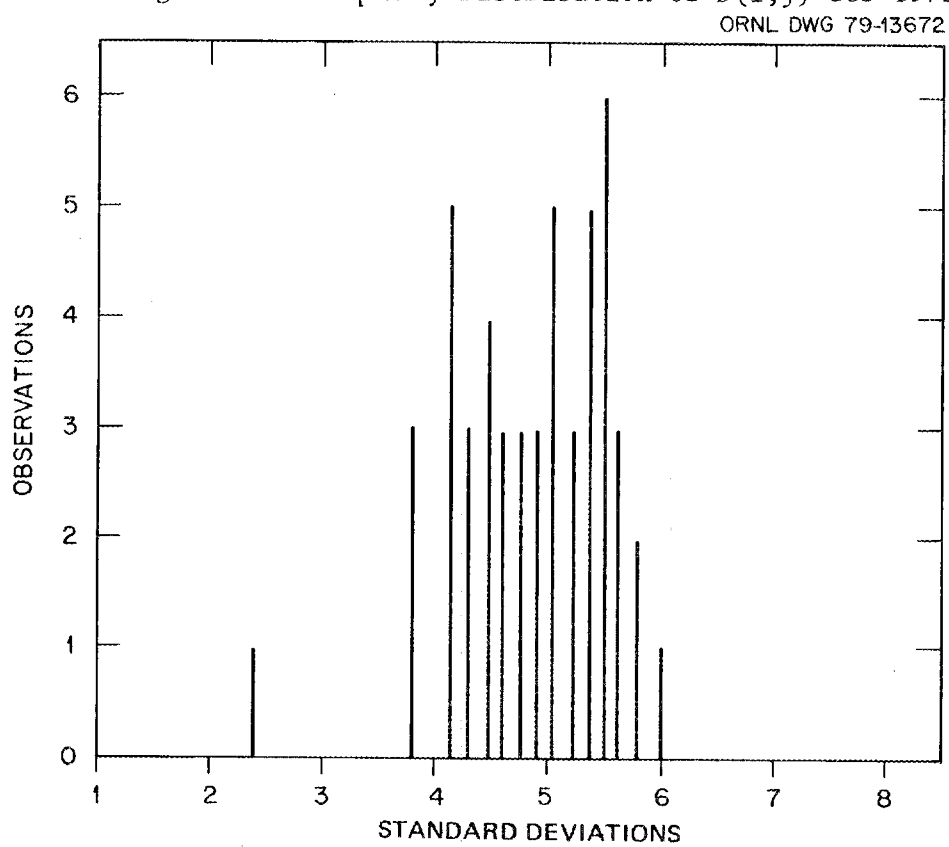

Fig. 3.2. Frequency Distribution for nLr for 1972.

$$\text{matrix } A = \begin{bmatrix} 0.2 & 0 & 0 & 0 & 0 & 3.2 & 1.1 & 0 \\ 0 & 0.2 & 0 & 0 & 0 & 2.3 & 0.7 & 0 \\ 0 & 0 & 0 & 0 & -0.5 & 3.3 & 0.8 & -.04 \\ 0 & 0 & 0 & 0 & 0 & 1.1 & 0.4 & 0 \\ 0 & 0 & 0 & 0 & f(n) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix},$$

$$\text{vector } B = \begin{bmatrix} -b_1 \\ -b_2 \\ -b_3 \\ b_4 \\ 0 \\ 0 \\ b_7 \\ 0 \end{bmatrix}.$$

(The coefficients of the matrix A have been chosen to be the first two significant digits of the coefficients of the respective estimated equations. The function f is a monotonically increasing function with upper bound 1 and lower bound >0.9 with $\{\prod_{n=1}^{\infty} f(n)\}$ convergent.)

It is not hard to see that this system behaves "in the large" much as models A and B. Iterative calculations yield

$$X(n) = A^n X(0) + \left(\sum_{i=1}^{n-1} A^i \right) B ,$$

and

$$A^n = \begin{bmatrix} 0.2^n & 0 & 0 & 0 & 0 & 3.2 & 1.1 & 0 \\ 0 & 0.2^n & 0 & 0 & 0 & 2.3 & 0.7 & 0 \\ 0 & 0 & 0 & 0 & -0.5 \prod_{i=0}^{n-1} f(i) & 3.3 & 0.8 & -0.4 \\ 0 & 0 & 0 & 0 & 0 & 1.1 & 0.4 & 0 \\ 0 & 0 & 0 & 0 & \prod_{i=0}^{n} f(i) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Thus the following results can be deduced from this analysis.

1. $$\text{LNTRVEH}(n) = \frac{T(n)/POP(n)}{1 - [T(n) + C(n)]/POP(n)}$$

is globally stable with regard to its initial value. Essentially this means that a perturbation in the original number of light trucks for all physically realizable stock adjustment models will not affect the long-range light truck forecasts.

In fact,

$$\frac{\partial[T(n)]}{\partial[T(o)]} = 0\left\{(0.2)^n \frac{T(n)}{T(o)}\right\}^* \quad \text{for model B ,}$$

$$\frac{\partial[T(n)]}{\partial[T(o)]} = 0 \quad \text{for model A .}$$

---

* $\frac{\partial[T(n)]}{\partial[T(o)]} = 0\ (0.2)^n \frac{T(n)}{T(o)}$ is defined to mean that there exits a constant L such that, for N sufficiently large and n > N,

$$\left|\frac{\partial[T(n)]}{\partial[T(o)]}\right| < L\ (0.2)^n \frac{T(n)}{T(o)} \quad .$$

2. A similar stability result holds for LNCVEH.

3. Perturbations in the initial values of LAGE and LPDI will affect both LNTRVEH and LNCVEH, and the magnitude of the effect is determined by the product of the size of the perturbation by the respective regression coefficient.

Specifically,

$$\frac{\partial[T(n)]}{\partial[AGE(o)]} = 0\left\{\frac{T(n)}{AGE(o)}\right\} \quad \text{for model B ,}$$

$$\frac{\partial[T(n)]}{\partial[PDI(o)]} = 0\left\{\frac{T(n)}{PDI(o)}\right\} \quad \text{for model B .}$$

Similar equalities hold for cars. Sensitivity of model A to the initial values requires a considerably more complicated expression but has the same flavor.

4. The effects of misspecification of the models insofar as the regression coefficients are concerned are also easily calculated. Of particular interest is

$$\frac{\partial[T(n)]}{\partial b_7} .$$

So long as the ratio

$$C(n)/POP(n)$$

remains bounded away from one, it is easy to see that

$$\frac{\partial[T(n)]}{\partial b_7} = 0\left\{(n-1) \ T(n)\right\}$$

for model B. This result indicates that the number of light trucks is particularly sensitive to the growth of PDI.

5. The values of LNTRVEH, LNCVEH, and LNVEH are dependent not only on the initial and terminal values of PDI but also on the path between these points. The path used for this model was determined by the end points and constant growth.

In summary, this technical analysis indicates that the models formulated here are not unreasonable. In the long run, they are insensitive to the initial number of cars or light trucks. However, they are sensitive to the population growth and particularly sensitive to the expected behavior of personal disposable income.

4. DISCUSSION OF MODEL REFINEMENTS, IMPROVEMENTS, AND SHORTCOMINGS

Several avenues for improvements of the model immediately suggest themselves, yet almost all depend on the greater availability and accuracy of light truck data than is presently at hand.

1. The actual number of light trucks used to generate the regression coefficients in this report was estimated from total truck inventory data from the *1975 Automobile Facts and Figures* and the ratio of light trucks per all trucks data from the 1963, 1967, and 1972 Truck Inventory and Use Surveys. These latter ratios were interpolated linearly for intervening years. Two sources of error are possible. The lesser one is that due to linear interpolation. The other is that the *Automobile Facts and Figures'* data are revised annually, sometimes significantly. (The sensitivity of the coefficients to the light truck inventory data has not yet been investigated.)

With the processing of the state-level Polk data for automobiles and light trucks, it should be possible to refine the regression analysis by cross-sectional time series analysis on more timely data as well as specific major end use analyses.

2. The variable AGE was interpolated. Other sources provide these data in the format appropriate to this study and hence obviate the necessity of interpolation. Such data should be used.

3. A case can justifiably be made that model B is a simultaneous equation model and should more appropriately be estimated by two-stage least squares or similar approach. How such an approach would affect the results is unknown at the present time.

5. CONCLUSIONS

There seems little doubt that the number of light trucks will increase in the near future, regardless of the measure used (actual numerical count, trucks per person, or truck per car ratio). Moreover, the general concensus seems to be that the light truck per person ratio will stabilize sometime in the next one to three decades. The time and level of truck per person ratio at which this stabilization will take place is an issue subject to less unanimity. Models A and B suggest that unless the economy slows, this stabilization will not occur before the year 2000. Certain of the L-K forecasts suggest stabilization at 0.14 truck per person by the year 1985 (Case IIA). For this same case, models A and B forecast 0.131 truck per person and 0.133 truck per person, respectively, in the year 2000.

There are, of course, many contingencies which neither models A and B nor the L-K forecasts consider: wholesale electrification of motor vehicles or abolishment of private ownership of vehicles, to name two. Hence, the forecasts are general indicators at best. Models A and B are open to critical review and for delicate and detailed policy questions these models should be supplemented by further analyses, both quantitative and qualitative. Attention should be directed to the plausibility of the forecasting scenarios and also to the reliability of the historical data which form the basis of any forecasts. Additional analytical work might involve time-series cross-sectional analysis as well as modeling each of the major light truck uses explicitly. Unfortunately, the quality of the data available for this study is such that even a sophisticated model may yield no additional insight.

REFERENCES

1. Linsey-Kaufman Company, *Projection of Light Truck Population to Year 2025*, ORNL/Sub-78/14285/1, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 1978.

2. U.S. Department of Commerce, Bureau of the Census, *1972 Census of Transportation*, "Truck Inventory and Use Survey — United States Summary," Series TC72-T52, Washington, D.C., 1973.

3. U.S. Department of Commerce, Bureau of the Census, *1963 Census of Transportation*, "Truck Inventory and Use Survey — United States Summary", Series TC63(A)-T61, Washington, D.C., April 1965.

4. U.S. Department of Commerce, Bureau of the Census, *1967 Census of Transportation*, "Truck Inventory and Use Survey — United States Summary", Series TC67(A)-T61, Washington, D.C., June 1969.

5. Motor Vehicle Manufacturers Association of the U.S., Inc., *1975 Automobile Facts and Figures*, p. 24, Detroit, 1975.

6. *Automotive News, 1965 Almanac Issue*, April 30, 1973, pp. 16, 36; *Automotive News, 1975 Almanac Issue*, April 23, 1975, p. 4: Slocum Publishing Co., Inc., Detroit.

7. *Business Week*, July 11, 1977.

8. W. F. Gay, *Energy Statistics*, U.S. Department of Transportation, p. 137, Washington, D.C., 1975.

9. Jack Faucett Associates, Inc., *Trucking Activity and Fuel Consumption 1973, 1980, 1985, and 1990*, Table 35, p. 59, Chevy Chase, Md., July 1976.

10. R. H. Goshorn, *Socio-Economic Factors Affecting Household Formation and Housing Size in the United States*, Oak Ridge National Laboratory, December 1977. Unpublished paper. (Computer print-out made available by Eric Hirst of ORNL.)

11. David Curry et al., *Transportation in America's Future: Potential for the Next Half Century*, prepared by Standford Research Institute

for the Department of Transportation, DOT-TPI-20-77-21, June 1977.

12. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States 1977*, Washington, D.C., 1977.

13. J. Johnston, *Econometric Methods*, McGraw-Hill, New York, 1972.

14. N. Draper and H. Smith, *Applied Regression Analysis*, John Wiley and Sons, Inc., New York, 1966.

15. J. Durbin, "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors Are Lagged Dependent Variables," *Econometrica* 38: 410-421, May 1970.

APPENDIX A

AUTOMOBILE FORECASTS

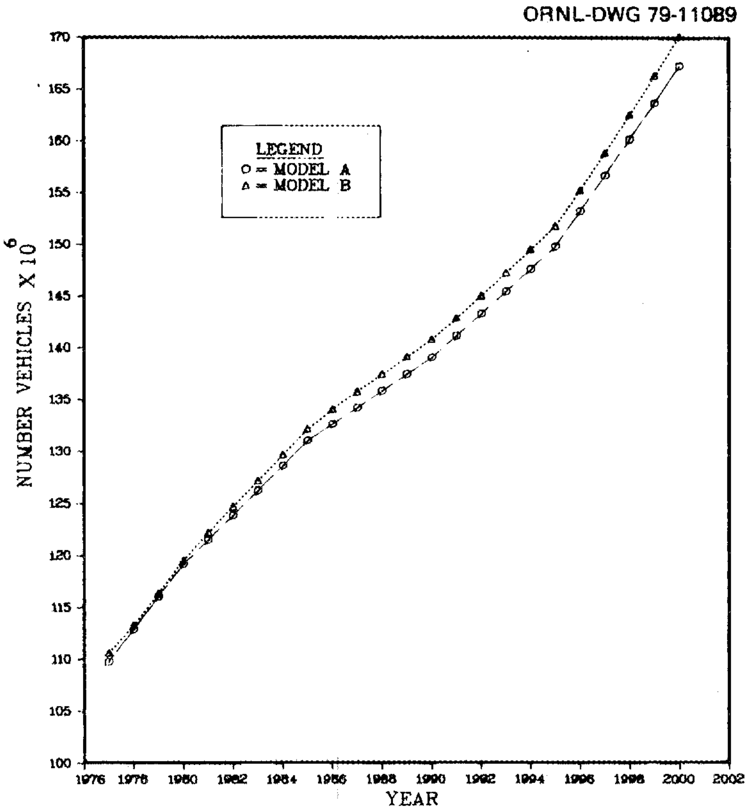

Fig. A.1. Automobile Forecast — Case I.

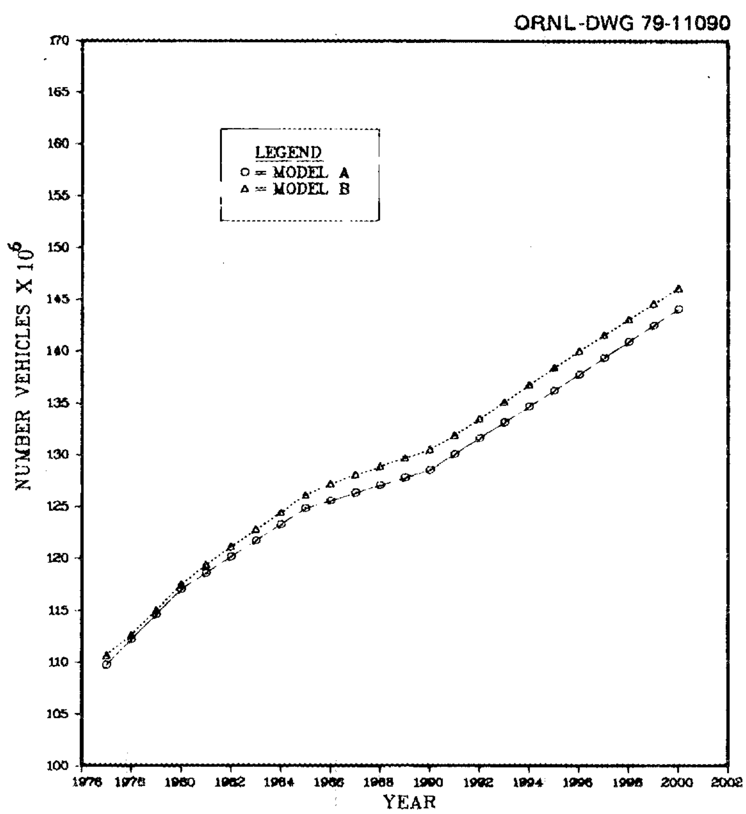

Fig. A.2. Automobile Forecast — Case II.

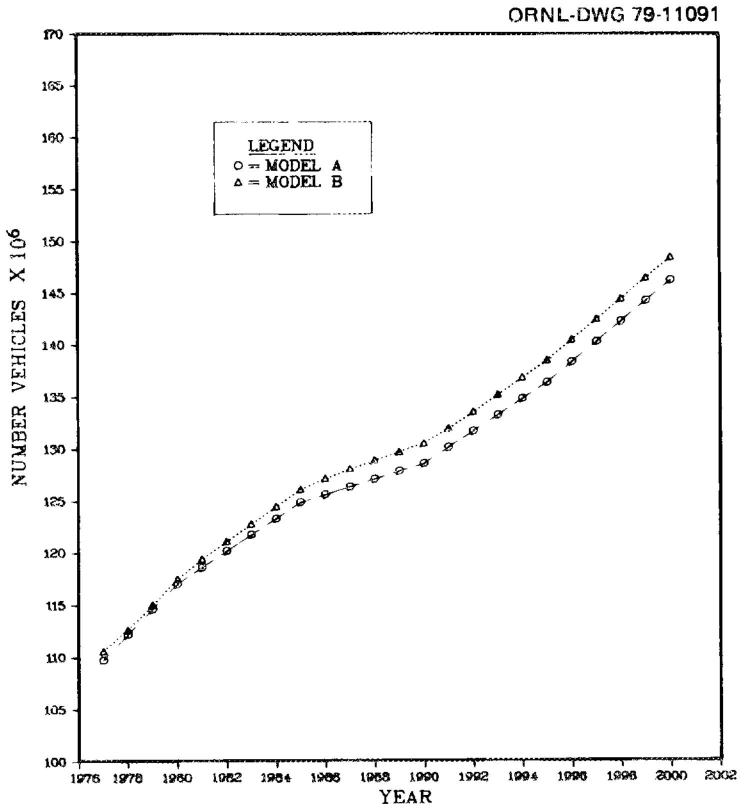

Fig. A.3. Automobile Forecast — Case IIA.

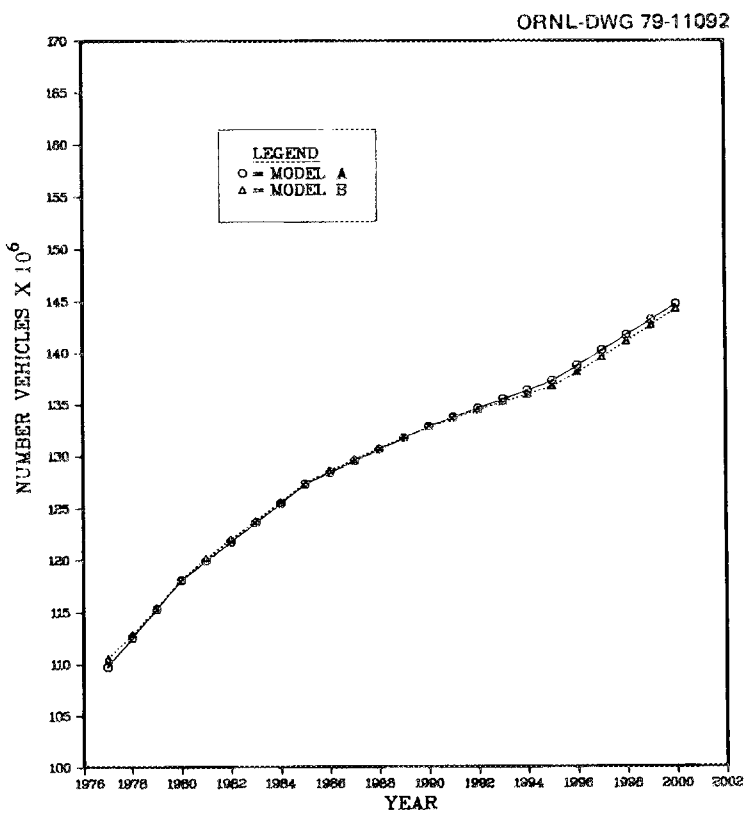

Fig. A.4. Automobile Forecast — Case III.

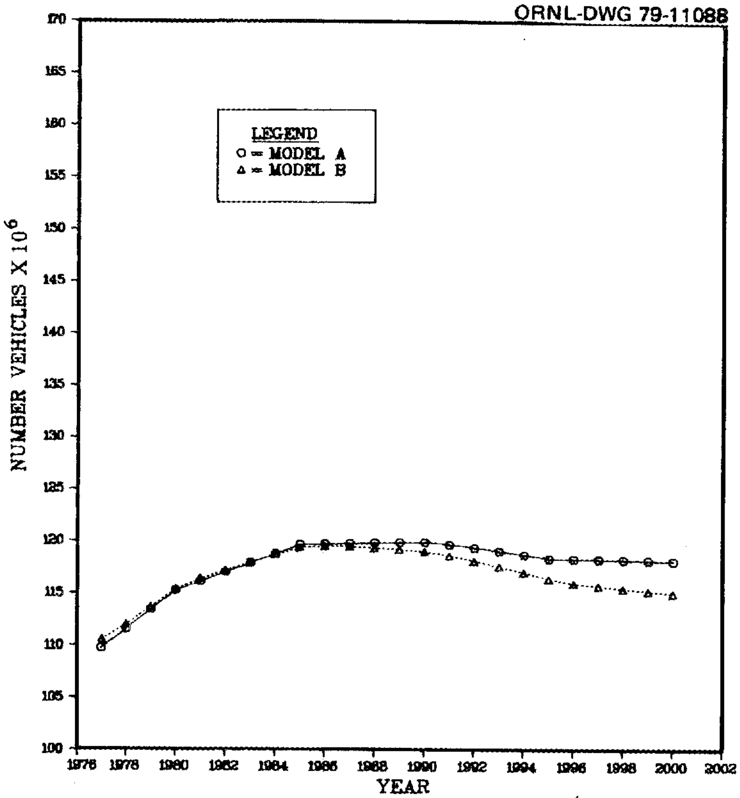

Fig. A.5. Automobile Forecast — Case IV.

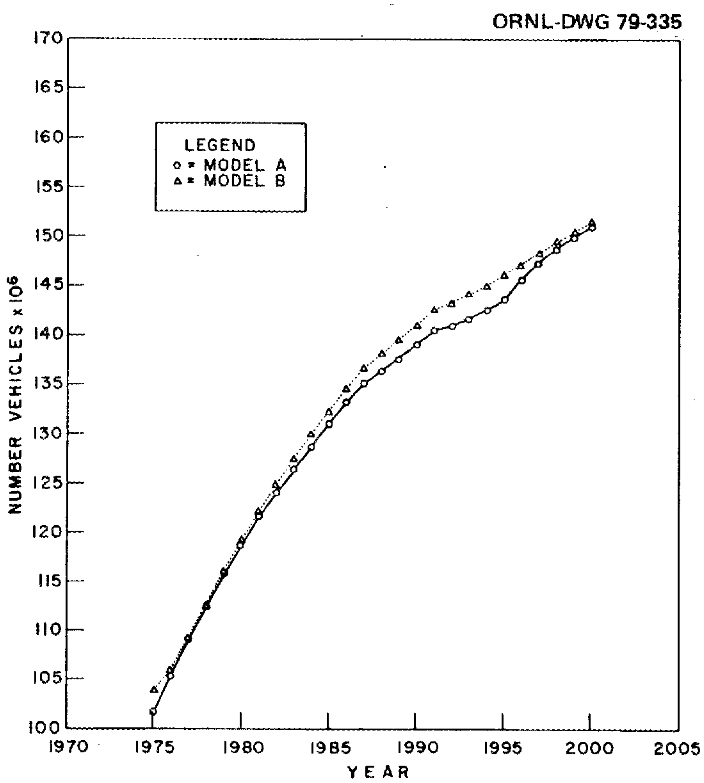

Fig. A.6. Automobile Forecast — Hirst Data.

APPENDIX B

LIGHT TRUCK AND AUTOMOBILE FORECASTS

MODEL A

CASE I	CAR	TR	STSC	CARPOP	TRPOP	VEHPOP	HHSZ
1975	0.10746E 03	0.18962E 02	0.17645E 00	0.50325E 00	0.88798E-01	0.59205E 00	0.29156E 01
1976	0.10979E 03	0.19628E 02	0.17878E 00	0.50847E 00	0.90903E-01	0.59937E 00	0.28936E 01
1977	0.11213E 03	0.20312E 02	0.18114E 00	0.51360E 00	0.93034E-01	0.60663E 00	0.28721E 01
1978	0.11450E 03	0.21015E 02	0.18354E 00	0.51864E 00	0.95190E-01	0.61383E 00	0.28511E 01
1979	0.11689E 03	0.21736E 02	0.18596E 00	0.52360E 00	0.97371E-01	0.62097E 00	0.28305E 01
1980	0.11929E 03	0.22477E 02	0.18842E 00	0.52847E 00	0.99576E-01	0.62805E 00	0.28105E 01
1981	0.12161E 03	0.23197E 02	0.19075E 00	0.53283E 00	0.10164E 00	0.63447E 00	0.27909E 01
1982	0.12396E 03	0.23936E 02	0.19310E 00	0.53711E 00	0.10372E 00	0.64083E 00	0.27718E 01
1983	0.12632E 03	0.24694E 02	0.19548E 00	0.54131E 00	0.10582E 00	0.64713E 00	0.27532E 01
1984	0.12870E 03	0.25469E 02	0.19789E 00	0.54543E 00	0.10794E 00	0.65337E 00	0.27350E 01
1985	0.13110E 03	0.26264E 02	0.20033E 00	0.54947E 00	0.11008E 00	0.65955E 00	0.27172E 01
1986	0.13268E 03	0.26699E 02	0.20124E 00	0.54992E 00	0.11066E 00	0.66059E 00	0.26998E 01
1987	0.13426E 03	0.27137E 02	0.20213E 00	0.55034E 00	0.11124E 00	0.66157E 00	0.26828E 01
1988	0.13585E 03	0.27579E 02	0.20302E 00	0.55071E 00	0.11180E 00	0.66251E 00	0.26663E 01
1989	0.13745E 03	0.28024E 02	0.20389E 00	0.55105E 00	0.11235E 00	0.66340E 00	0.26501E 01
1990	0.13906E 03	0.28473E 02	0.20476E 00	0.55135E 00	0.11289E 00	0.66424E 00	0.26343E 01
1991	0.14114E 03	0.29141E 02	0.20647E 00	0.55344E 00	0.11427E 00	0.66771E 00	0.26189E 01
1992	0.14325E 03	0.29821E 02	0.20818E 00	0.55550E 00	0.11564E 00	0.67115E 00	0.26038E 01
1993	0.14537E 03	0.30515E 02	0.20991E 00	0.55752E 00	0.11703E 00	0.67455E 00	0.25891E 01
1994	0.14752E 03	0.31221E 02	0.21164E 00	0.55950E 00	0.11841E 00	0.67791E 00	0.25747E 01
1995	0.14968E 03	0.31940E 02	0.21339E 00	0.56144E 00	0.11981E 00	0.68124E 00	0.25607E 01
1996	0.15283E 03	0.32894E 02	0.21523E 00	0.56708E 00	0.12205E 00	0.68913E 00	0.24507E 01
1997	0.15558E 03	0.33773E 02	0.21708E 00	0.57104E 00	0.12396E 00	0.69500E 00	0.23828E 01
1998	0.15813E 03	0.34621E 02	0.21894E 00	0.57413E 00	0.12570E 00	0.69983E 00	0.23360E 01
1999	0.16057E 03	0.35455E 02	0.22081E 00	0.57668E 00	0.12734E 00	0.70402E 00	0.23014E 01
2000	0.16294E 03	0.36286E 02	0.22269E 00	0.57888E 00	0.12891E 00	0.70779E 00	0.22747E 01

MODEL B

	TOTC	TOTT	TTTC	TOTCPO	TOTTPO	VEHCPO	ERR
1975	0.10812E 03	0.19240E 02	0.17795E 00	0.50633E 00	0.90100E-01	0.59643E 00	-0.93442E 00
1976	0.11072E 03	0.19940E 02	0.18009E 00	0.51278E 00	0.92347E-01	0.60513E 00	-0.12429E 01
1977	0.11317E 03	0.20646E 02	0.18243E 00	0.51834E 00	0.94561E-01	0.61290E 00	-0.13690E 01
1978	0.11559E 03	0.21368E 02	0.18486E 00	0.52359E 00	0.96792E-01	0.62038E 00	-0.14469E 01
1979	0.11802E 03	0.22111E 02	0.18734E 00	0.52871E 00	0.99048E-01	0.62775E 00	-0.15139E 01
1980	0.12047E 03	0.22873E 02	0.18986E 00	0.53372E 00	0.10133E 00	0.63505E 00	-0.15806E 01
1981	0.12287E 03	0.23625E 02	0.19228E 00	0.53833E 00	0.10351E 00	0.64184E 00	-0.16830E 01
1982	0.12527E 03	0.24389E 02	0.19470E 00	0.54278E 00	0.10568E 00	0.64846E 00	-0.17607E 01
1983	0.12768E 03	0.25171E 02	0.19715E 00	0.54712E 00	0.10786E 00	0.65499E 00	-0.18337E 01
1984	0.13011E 03	0.25973E 02	0.19962E 00	0.55138E 00	0.11007E 00	0.66145E 00	-0.19076E 01
1985	0.13256E 03	0.26794E 02	0.20213E 00	0.55557E 00	0.11230E 00	0.66786E 00	-0.19938E 01
1986	0.13441E 03	0.27335E 02	0.20338E 00	0.55710E 00	0.11330E 00	0.67041E 00	-0.23689E 01
1987	0.13609E 03	0.27810E 02	0.20435E 00	0.55786E 00	0.11400E 00	0.67186E 00	-0.25097E 01
1988	0.13774E 03	0.28272E 02	0.20526E 00	0.55838E 00	0.11461E 00	0.67299E 00	-0.25840E 01
1989	0.13938E 03	0.28733E 02	0.20615E 00	0.55880E 00	0.11520E 00	0.67399E 00	-0.26417E 01
1990	0.14103E 03	0.29197E 02	0.20703E 00	0.55917E 00	0.11577E 00	0.67493E 00	-0.26964E 01
1991	0.14303E 03	0.29836E 02	0.20860E 00	0.56084E 00	0.11699E 00	0.67783E 00	-0.25801E 01
1992	0.14514E 03	0.30528E 02	0.21033E 00	0.56285E 00	0.11838E 00	0.68124E 00	-0.26024E 01
1993	0.14731E 03	0.31243E 02	0.21209E 00	0.56494E 00	0.11982E 00	0.68477E 00	-0.26648E 01
1994	0.14950E 03	0.31974E 02	0.21387E 00	0.56703E 00	0.12127E 00	0.68830E 00	-0.27395E 01
1995	0.15172E 03	0.32720E 02	0.21566E 00	0.56909E 00	0.12273E 00	0.69182E 00	-0.28188E 01
1996	0.15394E 03	0.33487E 02	0.21753E 00	0.57119E 00	0.12425E 00	0.69544E 00	-0.17016E 01
1997	0.15619E 03	0.34272E 02	0.21942E 00	0.57328E 00	0.12579E 00	0.69907E 00	-0.11076E 01
1998	0.15846E 03	0.35072E 02	0.22133E 00	0.57533E 00	0.12734E 00	0.70267E 00	-0.78287E 00
1999	0.16075E 03	0.35888E 02	0.22325E 00	0.57735E 00	0.12889E 00	0.70624E 00	-0.61798E 00
2000	0.16307E 03	0.36719E 02	0.22518E 00	0.57932E 00	0.13045E 00	0.70977E 00	-0.55750E 00

LEGEND

CAR = NUMBER OF AUTOMOBILES (MODEL A)
TR = NUMBER OF TRUCKS (MODEL B)
STSC = TR/CAR
CARPOP = CAR/POPULATION
TRPOP = TR/POPULATION
VEHPOP = (TR + CAR)/POPULATION
HHSZ = HOUSEHOLD SIZE
TOTC = NUMBER OF AUTOMOBILES (MODEL B)
TOTT = NUMBER OF TRUCKS (MODEL A)
TTTC = TOTT/TOTC
TOTCPO = TOTC/POPULATION
TOTTPO = TOTT/POPULATION
VEHCPO = (TOTT + TOTC)/POPULATION
ERR = (CAR + TR) – (TOTC + TOTT)

MODEL A

CASE IIA	CAR	TR	STSC	CARPOP	TRPOP	VEHPOP	HHSZ
1975	0.10746E 03	0.18962E 02	0.17645E 00	0.50325E 00	0.88798E-01	0.59205E 00	0.29156E 01
1976	0.10918E 03	0.19516E 02	0.17874E 00	0.50832E 00	0.90860E-01	0.59918E 00	0.28938E 01
1977	0.11090E 03	0.20081E 02	0.18107E 00	0.51331E 00	0.92946E-01	0.60626E 00	0.28725E 01
1978	0.11262E 03	0.20657E 02	0.18343E 00	0.51821E 00	0.95056E-01	0.61327E 00	0.28518E 01
1979	0.11433E 03	0.21244E 02	0.18582E 00	0.52303E 00	0.97190E-01	0.62022E 00	0.28315E 01
1980	0.11604E 03	0.21843E 02	0.18824E 00	0.52777E 00	0.99346E-01	0.62711E 00	0.28116E 01
1981	0.11765E 03	0.22415E 02	0.19052E 00	0.53199E 00	0.10136E 00	0.63334E 00	0.27923E 01
1982	0.11926E 03	0.22998E 02	0.19284E 00	0.53613E 00	0.10338E 00	0.63951E 00	0.27734E 01
1983	0.12087E 03	0.23591E 02	0.19518E 00	0.54019E 00	0.10543E 00	0.64563E 00	0.27550E 01
1984	0.12247E 03	0.24194E 02	0.19755E 00	0.54418E 00	0.10750E 00	0.65168E 00	0.27370E 01
1985	0.12408E 03	0.24808E 02	0.19994E 00	0.54808E 00	0.10959E 00	0.65767E 00	0.27194E 01
1986	0.12487E 03	0.25075E 02	0.20081E 00	0.54838E 00	0.11012E 00	0.65850E 00	0.27022E 01
1987	0.12566E 03	0.25341E 02	0.20166E 00	0.54864E 00	0.11064E 00	0.65928E 00	0.26855E 01
1988	0.12645E 03	0.25606E 02	0.20250E 00	0.54886E 00	0.11115E 00	0.66000E 00	0.26691E 01
1989	0.12723E 03	0.25871E 02	0.20334E 00	0.54903E 00	0.11164E 00	0.66067E 00	0.26532E 01
1990	0.12801E 03	0.26134E 02	0.20416E 00	0.54917E 00	0.11212E 00	0.66129E 00	0.26376E 01
1991	0.12958E 03	0.26766E 02	0.20655E 00	0.55269E 00	0.11416E 00	0.66685E 00	0.26223E 01
1992	0.13115E 03	0.27407E 02	0.20897E 00	0.55614E 00	0.11622E 00	0.67235E 00	0.26075E 01
1993	0.13272E 03	0.28060E 02	0.21142E 00	0.55951E 00	0.11829E 00	0.67780E 00	0.25930E 01
1994	0.13429E 03	0.28723E 02	0.21389E 00	0.56281E 00	0.12038E 00	0.68319E 00	0.25788E 01
1995	0.13585E 03	0.29396E 02	0.21640E 00	0.56603E 00	0.12249E 00	0.68851E 00	0.25649E 01
1996	0.13815E 03	0.30100E 02	0.21787E 00	0.57226E 00	0.12468E 00	0.69693E 00	0.24535E 01
1997	0.14008E 03	0.30729E 02	0.21936E 00	0.57684E 00	0.12653E 00	0.70337E 00	0.23847E 01
1998	0.14183E 03	0.31322E 02	0.22085E 00	0.58057E 00	0.12822E 00	0.70879E 00	0.23371E 01
1999	0.14346E 03	0.31898E 02	0.22236E 00	0.58380E 00	0.12981E 00	0.71361E 00	0.23020E 01
2000	0.14502E 03	0.32466E 02	0.22387E 00	0.58659E 00	0.13134E 00	0.71804E 00	0.22747E 01

MODEL B

	TOTC	TOTT	TTTC	TOTCPO	TOTTPO	VEHCPO	ERR
1975	0.10812E 03	0.19240E 02	0.17795E 00	0.50633E 00	0.90100E-01	0.59643E 00	-0.93442E 00
1976	0.11013E 03	0.19830E 02	0.18006E 00	0.51272E 00	0.92323E-01	0.60505E 00	-0.12595E 01
1977	0.11196E 03	0.20418E 02	0.18237E 00	0.51821E 00	0.94506E-01	0.61272E 00	-0.13965E 01
1978	0.11374E 03	0.21015E 02	0.18476E 00	0.52340E 00	0.96703E-01	0.62010E 00	-0.14842E 01
1979	0.11551E 03	0.21624E 02	0.18720E 00	0.52844E 00	0.98925E-01	0.62736E 00	-0.15609E 01
1980	0.11727E 03	0.22245E 02	0.18969E 00	0.53338E 00	0.10117E 00	0.63456E 00	-0.16368E 01
1981	0.11897E 03	0.22849E 02	0.19206E 00	0.53793E 00	0.10332E 00	0.64124E 00	-0.17477E 01
1982	0.12064E 03	0.23457E 02	0.19444E 00	0.54231E 00	0.10545E 00	0.64776E 00	-0.18342E 01
1983	0.12230E 03	0.24075E 02	0.19685E 00	0.54659E 00	0.10759E 00	0.65419E 00	-0.19162E 01
1984	0.12397E 03	0.24703E 02	0.19928E 00	0.55080E 00	0.10976E 00	0.66056E 00	-0.19992E 01
1985	0.12563E 03	0.25344E 02	0.20174E 00	0.55492E 00	0.11195E 00	0.66687E 00	-0.20844E 01
1986	0.12670E 03	0.25712E 02	0.20294E 00	0.55640E 00	0.11292E 00	0.66932E 00	-0.24633E 01
1987	0.12760E 03	0.26014E 02	0.20387E 00	0.55710E 00	0.11358E 00	0.67067E 00	-0.26099E 01
1988	0.12845E 03	0.26299E 02	0.20474E 00	0.55755E 00	0.11415E 00	0.67170E 00	-0.26946E 01
1989	0.12929E 03	0.26580E 02	0.20559E 00	0.55790E 00	0.11470E 00	0.67260E 00	-0.27645E 01
1990	0.13011E 03	0.26859E 02	0.20643E 00	0.55821E 00	0.11523E 00	0.67344E 00	-0.28325E 01
1991	0.13152E 03	0.27430E 02	0.20855E 00	0.56097E 00	0.11699E 00	0.67797E 00	-0.26065E 01
1992	0.13310E 03	0.28081E 02	0.21098E 00	0.56439E 00	0.11907E 00	0.68347E 00	-0.26207E 01
1993	0.13472E 03	0.28761E 02	0.21348E 00	0.56795E 00	0.12125E 00	0.68919E 00	-0.27025E 01
1994	0.13636E 03	0.29456E 02	0.21602E 00	0.57148E 00	0.12345E 00	0.69494E 00	-0.28041E 01
1995	0.13795E 03	0.30164E 02	0.21860E 00	0.57496E 00	0.12569E 00	0.70065E 00	-0.29126E 01
1996	0.13939E 03	0.30715E 02	0.22035E 00	0.57739E 00	0.12723E 00	0.70462E 00	-0.18545E 01
1997	0.14073E 03	0.31232E 02	0.22193E 00	0.57949E 00	0.12861E 00	0.70809E 00	-0.11463E 01
1998	0.14205E 03	0.31745E 02	0.22348E 00	0.58148E 00	0.12995E 00	0.71143E 00	-0.64336E 00
1999	0.14336E 03	0.32261E 02	0.22503E 00	0.58341E 00	0.13129E 00	0.71470E 00	-0.26878E 00
2000	0.14468E 03	0.32784E 02	0.22659E 00	0.58532E 00	0.13263E 00	0.71795E 00	0.22400E-01

LEGEND

CAR = NUMBER OF AUTOMOBILES (MODEL A)

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TOTTPO = TOTT/POPULATION

VEHCPO = (TOTT + TOTC)/POPULATION

ERR = (CAR + TR) -- (TOTC + TOTT)

APPENDIX C

DESCRIPTION OF DATA

Table C.1. Description of Data

YR	POP[a]	HSE[b]	AGE[c]	HC[d]	PCT[e]	UNEMP[f]	TOTT[g]	TOTC[h]	GNP[i]	CS[j]	TS[k]
61	183.69	55.00	38.6	90.9	2205	6.7	8.269	63.420	755.3		
62	186.54	56.36	38.7	91.7	2272	5.5	8.750	66.110	799.1		
63	189.24	56.83	38.9	92.7	2321	5.7	8.911	69.055	830.7	7.941	0.934
64	191.89	57.62	39.0	93.8	2452	5.2	9.883	71.983	874.4	8.319	1.050
65	194.30	59.14	39.2	94.5	2571	4.5	10.586	75.251	925.9	9.546	1.194
66	196.56	60.11	39.3	97.2	2672	3.8	11.261	78.123	981.0	9.264	1.294
67	198.71	60.95	39.5	100.0	2740	3.8	11.908	80.414	1007.7	8.613	1.195
68	200.71	62.72	39.7	104.2	2812	3.6	12.482	83.591	1051.8	9.849	1.446
69	202.68	64.14	40.1	110.8	2833	3.5	13.197	86.852	1078.8	9.758	1.529
70	204.88	65.25	40.6	118.9	2879	4.9	13.858	89.230	1075.3	8.827	1.456
71	207.05	66.58	41.1	124.3	2958	5.9	14.664	92.754	1107.5	10.209	1.657
72	208.85	68.25	41.7	129.2	3062	5.6	15.713	96.980	1171.1	10.919	2.094
73	210.41	69.90	42.3	135.0	3225	4.9	17.211	101.763	1235.0	11.430	2.559
74	211.90	71.35	43.5	150.6	3143	5.6	18.562	105.290	1217.8	8.852	2.256

[a]POP = U.S. population in 10^6 people. Source: Department of Commerce, Bureau of the Census, Current Population Reports, Series P-25, Nos. 700 and 708.

[b]Number of households × 10^6 calculated on the basis of average household size. Source: Department of Commerce, Bureau of the Census, Population Characteristics, Series P-20, No. 313, September 1977.

[c]Percentage of population between the ages of 15 and 45 (interpolated). Source: Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1977,* Table 28, p. 27.

[d]Consumer price index for total housing. Source: President of the United States, Economic Report of the President, Table B-49, p. 313, Washington, D.C.

[e]Per capita personal disposable income in 1967 dollars. Source: President of the United States, Economic Report of the President, Table B-22, p. 283, Washington, D.C., January 1978.

[f]Unemployment rate for all workers. Source: President of the United States, Economic Report of the President, Table B-29, p. 291.

[g,h]Number of light trucks, automobiles × 10^6. Calculated on the basis of the 1963, 1967, and 1972 Truck Inventory and Use Surveys and the *1975 Automobile Facts and Figures,* Motor Vehicle Manufacturers Association of the U.S., Inc., Detroit, 1975, p. 24.

[i]Gross national product in 10^9 1972 dollars. Source: President of the United States, Economic Report of the President, Table B-10, p. 269, Washington, D.C., 1978.

[j]Car sales (both domestic and import sales in the United States). Sources: *Automotive News,* pp. 48, 68, 70 (1977); pp. 10, 54 (1976); pp. 10, 62 (1973); pp. 36, 16 (1965); p. 40 (1966); p. 19 (1969); p. 20 (1967); p. 14 (1971).

[k]Light truck sales in the United States. Sources: *Automotive News,* pp. 48, 68, 70 (1977); pp. 10, 54 (1976); pp. 10, 62 (1973); pp. 36, 16 (1965); p. 40 (1966); p. 19 (1969); p. 20 (1967); p. 14 (1971).

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