mum efficiency attainable by public transportation. The circumstances are ideal for efficient mode use, the market served has well-defined travel desire lines, and vehicles are operated near capacity. Private modes, in contrast, are operated with much lower vehicle occupancies and serve a relatively dispersed travel market.

ACKNOWLEDGMENT

The findings presented in this paper were prepared by a research team consisting of faculty and graduate students in the Department of Civil Engineering of the University of Illinois at Urbana-Champaign and staff members of the Chicago Area Transportation Study. The university-based portion of the research was supported by an UMTA research and training grant.

REFERENCES

1. D.E. Boyce and others. Urban Transportation Energy Accounts: Volume I--Procedures Manual. Department of Civil Engineering, Univ. of Illinois at Urbana-Champaign, Urbana, IL, 1981.
2. UTPS Reference Manual. Urban Mass Transportation Administration and Federal Highway Administration, U.S. Department of Transportation, 1979.
3. PLANPAC/BACKPAC: General Information. Federal Highway Administration, U.S. Department of Transportation, 1977.
4. Energy Study of Rail Passenger Transportation. Stanford Research Institute, Menlo Park, CA, Vol. 2, 1977.
5. UTPS Characteristics of Urban Transportation Systems. Urban Mass Transportation Administration and Federal Highway Administration, U.S. Department of Transportation, 1979.
6. L. Evans, R. Herman, and T.N. Lam. Gasoline Consumption in Urban Traffic. General Motors Research Laboratories, Warren, MI, Res. Publ. GMR-1949, 1976.
7. M. Chang, L. Evans, R. Herman, and P. Wasielewski. Gasoline Consumption in Urban Traffic. TRB, Transportation Research Record 599, 1976, pp. 25-30.
8. P.J. Claffey. Running Costs of Motor Vehicles as Affected by Road Design and Traffic. NCHRP, Rept. 111, 1971.

Publication of this paper sponsored by Committee on Energy Conservation and Transportation Demand.

Short-Term Forecasting of Gasoline Demand

JOHN W. HARTMANN, FRANK E. HOPKINS, AND DERRIEL B. CATO

Techniques used recently by the U.S. Department of Energy to forecast short-term demand for motor-vehicle gasoline are reviewed. Techniques used during and before 1979 are discussed briefly, and the rationale for the development of new methods during 1980 is also presented. Because the forecasting effort is an ongoing one, the procedures evolve over time. Only the techniques developed during 1980 are treated in detail, but a brief discussion and summary of the older methods are provided for comparison purposes. The current forecasting technique relies on predetermined parameter values rather than econometrically estimated values. This is the result of an evaluation of the econometric estimates. The new procedures have resulted in improved forecast accuracy and have anticipated the downturn in motor-vehicle gasoline demand that occurred in 1980. The current model computes annual demand for 1980 within 1.0 percent of actual demand, and the average error for the monthly demand estimates during 1980 is less than 2.5 percent of actual demand. The current techniques can be used to project the effects of various policy options, such as improved mileage requirements or gasoline tax levies.

The Short-Term Analysis Division (STAD) in the Energy Information Administration (EIA) of the U.S. Department of Energy is responsible for projecting demands, supplies, and prices of all energy products on a monthly basis, nationally. To do this, STAD uses the Short-Term Integrated Forecasting System (STIFS) (1), which is an iterative balancing procedure, and several "satellite" demand models, one of which is the Motor Gasoline Demand Model. This paper describes the activities that STAD has undertaken in its search for a credible procedure for forecasting the demand for gasoline for use in STIFS.

There are several reasons for undertaking the development of a new short-term forecasting model for motor gasoline demand for STIFS:

1. Several past studies have examined the demand for motor-vehicle gasoline on the Petroleum Administration for Defense Districts (PADD) level. STIFS requires a national basis. STAD felt that one national model could replace the five separate PADD models previously developed.
2. Gasoline prices were relatively constant over the estimation period of the earlier models. However, changes in gasoline price have recently become volatile. This volatility has led to the notion that perhaps a shift in demand is taking place.
3. Several regional price elasticities in the PADD-level model used for the EIA 1978 Annual Report (2) were estimated to be insignificantly different from zero. The rapid increases in price and the effect on demand belie this finding.
4. The linear structure of the gasoline model used in the EIA February 1980 Short-Term Energy Outlook (3) led to large elasticities when faced with the rapid price increases in 1979 and 1980 following the Iranian revolution. The February report used both an econometric methodology and, in the appendix, a simple parametric procedure.

These considerations led to the development of the current gasoline demand model, which underlies the demand projections for the EIA 1979 Annual Report to Congress (4) and subsequent Short-Term Energy Outlooks following the February 1980 report. The parameters of the current model are specified rather than econometrically estimated. This is an interim methodology until a behavioral model that uses household data currently being collected by EIA can be estimated.

EIA's early gasoline models were typically linear regression models. Demand for gasoline was the dependent variable, and real price, real disposable

Table 1. Short-term gasoline demand models: 1975-1980.

Model Formulators	Estimation Date	Dependent Variable			Structure
		Frequency	Level	Time Period	
Alt-Lady	1975	Monthly	National	1969-1973	Regressed demand for motor-vehicle gasoline on 11 monthly dummy variables and real price of motor-vehicle gasoline
Alt-Bopp	1976	Monthly	National	1968-1975	Log linear, regressed demand on relative price of gasoline, real income, 12-month lag demand, embargo dummy
Gaynor-Donnelly	1977-1978	Quarterly	PADD level	Third quarter 1975-second quarter 1976	Linearly regressed demand on quarterly prices, income, and population
Klemm-Bopp	1978	Monthly	National	1968-1977	Log linear, regressed demand on income, retail price index for gasoline, 12-month lag demand
Atkinson-Borg[a]	1978	Quarterly	PADD level	First quarter 1975-fourth quarter 1976	Pooled cross-section data, regressed gasoline use on price, income, and heating-degree days for quarters 1 and 4
Hartmann-Hopkins	1979	Monthly	National	June 1975-August 1979	Regressed gasoline use on two cyclic variables, rapidly changing real prices, steady real prices, real income, and four dummy variables for January, June, August, and December
Rodekohr	1980	Monthly	National	1968-1978	Log linear, regressed per capita consumption on real per capita income, real price, per capita consumption lagged 12 months, and an embargo dummy
Hartmann-Cato[b]	1980	Monthly	National	1975-1979	Assumed price and income elasticity values taken from literature; lagged consumption, lagged real price, and lagged income included as predicting variables

[a] Gasoline use is defined as demand x (efficiency/stock).
[b] This model was used for the 1979 Annual Report to Congress (4) and the Short-Term Energy Outlook (3) of May, August, and November 1980 and February 1981.

personal income, fleet fuel efficiency, and fleet size were the typical independent variables. In some early models, other factors, such as a weather variable, also appeared as independent variables. The seasonal variations were "explained" by a weather variable, monthly dummy variables for various months, or cyclic variables such as the sine and cosine functions over time.

Later EIA models estimated demand in logarithmic terms--that is, regressed log of demand on the logged values of the independent variables. This led to constant monthly elasticities. The introduction of lagged variables on the right-hand side of the equation made the model estimates more theoretically palatable, but the usual problem of serial correlation required the use of appropriate statistical estimation techniques.

The short-term models proposed between 1975 and 1980 are described briefly in Table 1. The models were reestimated by using monthly data for July 1975 through August 1979. Table 2 gives the results of the reestimations, and Table 3 shows the results for the Atkinson-Borg demand model [1978 Annual Report model (5)].

An examination of the significance and the signs and magnitudes of the coefficient estimates shows the deficiencies and the strengths of the models. Table 2 also gives estimations of the reduced-form linear-elasticity and constant-elasticity models for purposes of comparison. Both of these results are poor: The R^2 is only 0.31 in both cases. The signs on the income, automobile efficiency, and fleet-size parameter estimates are inconsistent with their theoretically expected signs. These reduced-form models are therefore inadequate.

In models in which a 12-month lagged dependent variable appears on the right-hand side, R^2 improves considerably, but unusual behavior in a month of the last year is perpetuated in simulations 12 months later.

The Hartmann-Hopkins model was developed in December 1979 as a synthesis of previous efforts. The dependent variable is a proxy for vehicle miles. This is consumption per automobile divided by average miles per gallon. The independent variables include (a) the seasonal sine and cosine and (b) dummy variables, which were found useful in the Alt-Lady demand model. Both income and prices are statistically significant and of the expected sign. The price variable has been divided into two periods: One price variable records prices during a period of stable real prices from March 1976 through December 1978, and the other covers the periods of rapidly changing real prices from July 1975 through February 1976 and from January 1979 through August 1979. This was done in the belief that responses to price are different for these time periods.

A comparison of Federal Highway Administration (FHWA) data (monthly gasoline demand data reported by the states) and Joint Petroleum Reporting System (JPRS) data shows that a difference exists and that it is growing. This is a result of the different points of data collection. The FHWA data are derived from state gasoline drawdowns of primary stocks at refineries and bulk terminals. There is evidence that additional gasoline imports and recycled petrochemical byproducts are blended into the gasoline supplies between the refiner and the wholesale stages. In STIFS, the estimation of gasoline demand has two primary functions. The first is to measure the consumption of gasoline by automobiles, which corresponds to an FHWA measurement concept. The second is to estimate the crude-oil imports needed in refineries to produce gasoline, which corresponds to a JPRS concept.

The FHWA annual data have been found to be more accurate than the JPRS data for measuring gasoline consumption. The monthly pattern of the JPRS data series best captures the refinery production cycle required by STIFS. EIA is currently in the process of revising its data collection form to include the production of gasoline at blending stations, which will bring the JPRS series closer to the FHWA series.

The following three-step methodology was used to forecast monthly gasoline demand in the February 1980 Short-Term Energy Outlook (3):

1. Specify the annual relation between gasoline demand and exogenous variables: national income, price of motor gasoline, automobile fleet efficiency, and stock of motor vehicles.
2. Calculate the annual level of gasoline demand for 1980 based on the FHWA 1979 estimate. Assumptions about price, stock, and efficiency were entered into the relation as specified in the first step.
3. Forecast a monthly distribution of gasoline demand. This was done by using a regression equation based on JPRS data.

This methodology gave an annual estimate of gasoline demand that was consistent with FHWA data and that used the seasonal patterns associated with JPRS information.

An estimate of gasoline demand was made by using the structural relation given below [a proxy for vehicle miles traveled per car (use) was calculated as a function of seasonal factors, monthly adjustments, price, and income]:

Table 2. Results of demand model reestimations.

Model	Dependent Variable	Independent Variable	Estimated Coefficient	t-Statistic	R^2 of Regression	Number of Observations	Standard Error of Regression	Procedure
Alt-Lady	Demand for motor-vehicle gasoline	Constant	9.93	14.46	0.59	50	0.27	Ordinary least squares estimation
		January dummy	-0.61	-3.26				
		February dummy	-0.40	-2.12				
		March dummy	-0.15	-0.79				
		April dummy	0.00	0.02				
		May dummy	0.00	0.32				
		June dummy	0.46	2.41				
		July dummy	0.21	1.15				
		August dummy	0.34	1.86				
		September dummy	-0.18	-0.10				
		October dummy	-0.10	-0.51				
		November dummy	-0.15	-0.81				
		Real price	-0.08	-4.06				
Alt-Bopp	Demand for motor-vehicle gasoline	Constant	5.75	6.04	0.74	50	0.19	Ordinary least squares estimation
		Real income	-0.00	-1.12				
		Real price	-0.09	-6.40				
		Demand lagged 12 months	0.83	8.98				
Klemm-Bopp		Constant	3.12	3.23	0.75	50	0.03	Ordinary least squares estimation
		Log of real income	-0.16	-1.14				
		Log of real price	-0.46	-6.14				
		Log of demand lagged 12 months	0.81	9.03				
Hartmann-Hopkins	Use = (efficiency/demand x stock of vehicles)	Constant	67.11	5.79	0.84	49	2.12	Cochrane-Orcutt interative procedure, final value of RHO = -0.28
		Sine function	1.86	4.15				
		Cosine function	3.15	4.93				
		Real income per capita	0.02	6.75				
		Rapidly changing real price	-0.90	-5.32				
		Steady real price	-0.84	-4.62				
		January dummy	-4.00	-2.98				
		June dummy	3.46	2.37				
		August dummy	2.68	1.98				
		December dummy	4.36	3.26				
Rodekohr[a]	Log of per capita demand	Constant	1.15	2.92	0.90	113	0.03	Cochrane-Orcutt interative procedure, final value of RHO = -0.08
		Log of real income per capita	0.30	4.48				
		Log of real price	-0.13	-4.01				
		Log of per capita demand lagged 12 months	0.79	17.22				
		Embargo dummy	-0.07	-5.99				
Basic Reduced-Form	Demand for motor-vehicle gasoline	Constant	-4.07	-0.56	0.31	50	0.31	Ordinary least squares estimation, linear elasticity
		Real income per capita	0.00	-0.46				
		Real price	-0.06	-1.53				
		Fleet efficiency	0.02	1.01				
		Fleet size	-0.09	-0.60				
Basic Reduced-Form	Log of demand for motor-vehicle gasoline	Constant	-12.60	-0.97	0.31	49	0.40	Ordinary least squares estimation, constant elasticity
		Log of real income per capita	-0.60	-0.48				
		Log of real price	-0.29	-1.50				
		Log of fleet efficiency	3.53	0.94				
		Log of fleet size	-1.14	-0.53				

[a] Estimation period = January 1969 through June 1978.

Table 3. Atkinson-Borg demand model.

	PADD 1		PADD 2		PADD 3		PADD 4		PADD 5	
Coefficient	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	-5.911	0.433	-6.202	0.539	-6.445	0.277	-6.445	0.722	-6.636	0.275
Price	-0.240	0.873	-0.240	0.873	-0.130	0.061 5	-0.130	0.061 5	-0.130	0.061 5
Income	0.620	0.169	0.869	0.344	0.622	0.153	0.730	0.441	0.845	0.087 7
Winter heating degree days	-0.007 72	0.00 803	-0.0107	0.001 73	-0.008 32	0.001 50	-0.0232	0.002 61	-0.0104	0.006 40
R^2[a]	0.935		0.768		0.778		0.866		0.975	
Durbin-Watson statistic[a]	0.910		1.930		2.130		1.800		1.200	

Note: Dependent variable = vehicle use; estimation period = first quarter 1975 to fourth quarter 1976.

[a] Generated by using generalized least squares estimation with one iteration on the data after full-information-maximum-likelihood estimation resulted in convergence. The statistics are therefore representative but not exact.

$$\text{Gasoline demand} = [(\text{miles traveled/vehicle}) \times \text{number of vehicles}] \div \text{fuel efficiency} \quad (1)$$

or, in units,

$$[(\text{miles/vehicle}) \times \text{vehicles}]/(\text{miles/gallon}) = (\text{miles/vehicle}) \times \text{vehicles} \times (\text{gallons/mile}) = \text{gallons} \quad (2)$$

The model used in the 1979 Annual Report (4) specifies gasoline use more fully than the February 1980 Short-Term Energy Outlook model (3) by recognizing that consumer reactions to price changes are characterized by rigidities that arise from habit, lack of substitutes (alternative modes of travel), and information delays. Thus, the total impact of a price change on demand will not be realized within a one-month period and may require several months. The current model also attempts to separate total use into automobile use and other use, which includes light trucks, school buses, and nonhighway equipment. Efficiency improvements and vehicle stock changes are exogenous, as in the previous model. Monthly seasonal factors are now derived by decomposing the demand series into trend, seasonal, and irregular components.

The equations of the 1979 Annual Report model are as follows: For automobile trend demand,

$$\begin{aligned}\text{USE} = \text{EXP}[&\text{CONSTANT} - 0.11\,\text{LN}(\text{RPMG/MPG}) \\ &+ (0.11)(0.50)^{12}\,\text{LN}(\text{RPMG/MPG})_{-12} + (0.79)\text{LN}(\text{RY}) \\ &- (0.79)(0.50)\text{LN}(\text{RY})_{-1} + (0.50)\text{LN}(\text{USE})_{-1}]\end{aligned} \quad (3)$$

$$\text{AUTO} = \text{USE} \times \text{KCARS}/(365 \times 42 \times \text{MPG}) \quad (4)$$

For nonautomobile trend demand,

$$\text{USE} = \text{EXP}[\text{CONSTANT} - 0.10\,\text{LN}(\text{RPMG/MPG})_{-12} + 0.79\,\text{LN}(\text{RY})] \quad (5)$$

$$\text{OTHER} = \text{USE} \times (1 + \%\text{KCARS})/(365 \times 42 \times (1 \times \%\text{MPG}) \quad (6)$$

For total demand,

$$\text{TOTAL} = \text{SEASONAL FACTOR} \times (\text{AUTO} + \text{OTHER}) \quad (7)$$

where

EXP = exponential,
LN = natural logarithm,
-1 = 1-month lag,
-12 = 12-month lag,
% = percentage change,
AUTO = automobile gasoline demand,
OTHER = nonautomobile gasoline demand,
RY = real income,
RPMG = real price,
MPG = efficiency, and
KCARS = fleet size.

Seasonal factors are as given below:

Month	Factor
January	0.9218
February	0.9685
March	0.9870
April	1.0139
May	0.9973
June	1.0576
July	1.0208
August	1.0366
September	1.0002
October	0.9880
November	0.9964
December	1.0073

The forecasting methodology consists of the following procedures:

1. Specify the parameters of the automobile gasoline model and other gasoline model by using estimates from the literature. Table 4 summarizes the literature search.
2. Forecast the monthly trend in automobile gasoline use as a dynamic function of cost per mile of travel and disposable income; then forecast monthly automobile gasoline demand as the product of automobile fleet size, efficiency improvements, and seasonal factors.
3. Forecast monthly nonautomotive gasoline demand as a function of the cost per mile of travel lagged one year, disposable income, nonautomobile fleet size, efficiency improvements, and seasonal factors.

Gasoline consumption is separated into automobile consumption (private plus commercial) and other consumption, based on 1976 FHWA data. The automobile demand component of personal vehicles plus single-unit trucks is approximately 75 percent, which is used to estimate automobile and nonautomobile demand for gasoline.

Consumers respond to increases in gasoline prices by decreasing miles traveled and increasing vehicle efficiency by purchasing new, more efficient vehicles and retiring older, less efficient vehicles. However, the full impacts of these two effects take time to be realized.

Vehicle efficiency improvements for the fleet are limited by the efficiency of new cars and by the purchase of new cars. The full impact of efficiency improvements in the stock of vehicles requires several years to take effect. Changes in miles driven may be fully realized within one year in response to price change. Significant changes in vehicle travel, however, may not be realized in one month and may take several months.

Short-term monthly forecasts may not be affected by efficiency improvements except those that have been set in motion by previous price changes. Monthly forecasts can be affected significantly by rigidities in the adjustment of gasoline use rates.

The size of the one-month elasticity, as well as the length of the lag, is highly speculative. The procedure described below assumes that

1. The adjustment process is geometric,
2. The adjustment takes place within one year following a price change,
3. The real income effect has an immediate impact on the use of gasoline due to a decrease in purchasing power, and
4. The price and substitution effects have a slow impact because of habit, information delays, carpool formation, search time for alternatives, and the switch to diesel.

Figure 1 shows the geometric adjustment process. The top panel shows a step increase in the cost per mile of travel (price of gasoline divided by efficiency). The middle panel shows the cumulative elasticity (in absolute value) due to decreases in use (the first impact) and efficiency improvements (the longer-term impact). The lower panel shows the corresponding decrease in gasoline demand.

The EIA Midrange Energy Forecasting System (MEFS) transportation demand model (14) estimate of a one-year elasticity of the cost per mile of travel is -0.25. A recent review of the literature gives a range of -0.1 to -0.25 (Table 4).

The price elasticity for "other" consumption was obtained from the EIA-MEFS truck model. The truck

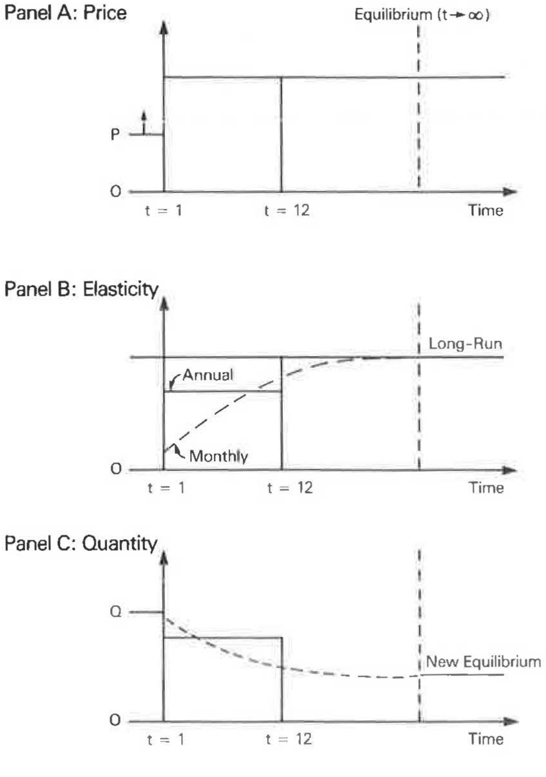
Table 4. Summary of literature survey.

Source	Price Elasticity: Type	Price Elasticity: Elasticity	Price Elasticity: Standard Error	Model Type	Sample Information: Frequency	Sample Information: Level	Sample Information: Period	Sample Information: Type of Data
Cato (5)	One year	-0.25	0.070	Random coefficient, flow-adjustment regression model, log linear specification; demand expressed as function of price and income and lagged one year	Annual	Sixteen OECD countries, including United States	1962-1977	Temporal cross section
Data Resources, Inc. (6)	One quarter	-0.10[a]	0.070	Gasoline demand per capita estimated as function of real price, income, and automobile stock; log linear specification; past behavior captured in four-quarter lag structure for price and income	Quarterly	United States		Time series, retail prices, excluding taxes
Fainer (7)	One year	-0.181	0.039	Demand expressed as log linear function of price and income and lagged one year; dummy variable for each country variant	Annual	Four major European countries	1960	Temporal cross section
Houthakker and others (8)	One quarter	-0.075[b]	0.013	Dynamic flow-adjustment model, log linear specification, demand a function of price and income and lagged one quarter	Quarterly	United States (48 states)	1963-1972	Temporal cross section
Houthakker and Kennedy (8)	One year	-0.465	0.105	Same as Houthakker and others, except annual specification	Annual	Twelve OECD countries, including United States	1960-1972	Temporal cross section
Rodekohr (9)	One to 12 months[c]	-0.128	0.032	Log linear, demand regressed on price and income and lagged 12 months; embargo dummy	Monthly	United States	Jan. 1968-Dec. 1978	Time series
Rodekohr (10)	One year	-0.163	0.034	Random coefficient, flow-adjustment regression model, log linear specification; demand expressed as function of price and income and lagged one year	Annual	Major European OECD countries	1962-1976	Temporal cross section
Sweeney (11)	One year	-0.227[d] -0.232[e] -0.300[f]	0.060[d] 0.050[e] 0.050[f]	Vintage capital-adjustment model; vehicle miles per capita a function of fleet efficiency, automobile stock, price, income, and the specified exogenous variables	Annual	United States	1957-1977	Time series
Wildhorn and others (12)	One year	-0.370	0.110	Five-equation recursive system, containing three equations that estimate automobile ownership as function of car price, income, and gasoline price and two equations describing VMT and efficiency	Annual	United States	1954-1972	Time series

Note: OECD = Organization for Economic Cooperation and Development.

[a] Four-quarter price elasticity = -0.28.
[b] Four-quarter price elasticity = -0.2.
[c] Elasticity constant over 12-month period.
[d] Person-hours included as exogenous variable.
[e] Person-hours and unemployment rate included as exogenous variables.
[f] Person-hours, unemployment rate, and new-car registrations per capita included as exogenous variables.

Figure 1. Geometric flow-adjustment process.



model contains a one-year delay in the response of truck travel to changes in average fuel costs (the average price of diesel and gasoline), which yields a zero elasticity in the first year and a second-year elasticity of average cost of -0.5.

There is little or no reliable information concerning the short-term effect following income changes. A reasonable assumption is that the effect is constant throughout the year. The EIA-MEFS annual automobile model estimate of the income elasticity is 0.79. The range of income elasticity in the literature is between 0.6 and 1.0 in those annual models that do not force the elasticity to increase over time.

Seasonal factors estimated for the 1979 Annual Report (4) are based on the decomposition of a monthly time series into trend, seasonal, and irregular components. In general, any monthly time series (Q) can be assumed to be the product of the trend of the series (T), a seasonal component (S), and an irregular component (I), or Q = T x S x I. The Bureau of the Census X-11MULT Seasonal Adjustment Program (15) was used to derive the seasonal factors.

Automobile use (USE) is specified as a geometric function of the logarithm of the real cost per mile [real price of gasoline (RPMG) divided by the average efficiency of the automobile stock], real personal disposable income (RYD), and USE lagged 1 month. Also included in Equation 3 are a 1-month lag on income, which has the effect of keeping the income elasticity constant, and a 12-month lag in the cost per mile, which assumes that all adjust-

Table 5. Comparison of recent model backcasts of gasoline demand for 1979.

	Gasoline Demand (000 000 bbl/day)						
		Rodekohr Model		Hartmann-Hopkins Model		1979 Annual Report Model	
Month	Actual	Backcast	Error	Backcast	Error	Backcast	Error
January	6.830	7.292	0.462	6.913	0.083	7.159	0.329
February	7.254	7.198	-0.056	7.185	-0.069	7.604	0.350
March	7.229	7.574	0.345	7.194	-0.035	7.646	0.417
April	7.055	7.674	0.619	7.151	0.096	7.521	0.466
May	7.213	7.449	0.236	7.144	-0.069	7.693	0.480
June	7.191	7.714	0.523	7.327	0.136	7.670	0.479
July	6.902	7.619	0.717	6.886	-0.016	7.432	0.530
August	7.330	7.505	0.175	6.909	-0.421	7.882	0.552
September	6.881	7.440	0.559	6.529	-0.352	7.332	0.451
October	7.020	7.392	0.372	6.386	-0.634	7.426	0.406
November	6.791	7.477	0.686	6.264	-0.527	7.197	0.406
December	6.730	7.535	0.805	6.413	-0.317	7.181	0.451
1979 average	7.034	7.489	NA	6.858	NA	7.479	NA

Table 6. Comparison of February 1981 model backcast with actual data for 1980.

	Gasoline Demand (000 000 bbl/day)			
Month	Actual[a]	Model	Difference	Difference (%)
January	6.335	6.273	-0.062	-0.98
February	6.594	6.552	-0.042	-0.64
March	6.411	6.523	0.112	1.75
April	6.799	6.535	-0.264	-3.88
May	6.726	6.523	-0.203	-3.02
June	6.661	6.914	0.253	3.80
July	6.735	6.711	-0.024	-0.36
August	6.646	6.891	0.245	3.69
September	6.515	6.640	0.125	1.92
October	6.621	6.627	0.006	0.00
November	6.344	6.674	0.330	5.20
December	6.616	6.701	0.085	1.29
Average	6.583	6.631	0.146[b]	2.21

[a] From Monthly Energy Review, March 1981; last three months are preliminary.
[b] Average of absolute values.

ments in the use rate occur within a 12-month period.

The one-month real price elasticity is assumed to equal -0.11, which, because of the assumed speed-of-adjustment coefficient, yields a 12-month price elasticity of -0.22 [i.e., -0.11 x 1/(1 - 0.5) = -0.22]. The income elasticity is assumed to equal 0.79, which is the value from the MEFS automobile model.

Equation 4 yields the monthly trend of gasoline demand as the product of the stock component and the efficiency component. Forecasts for the growth of automobile stock and the average efficiency of the stock are based on forecasts contained in the February 28, 1980, control solution put out by Data Resources, Inc.

Nonautomobile gasoline demand is forecast more simply than automobile demand. Based on the MEFS truck model, it is assumed that there is a 12-month lag in the response of truck miles to a price change. Equation 6 incorporates an assumed increase in truck stocks and efficiency increases equal to those assumed for automobiles. The price elasticity is assumed to equal -0.10 and the income elasticity to equal 0.79. Automobile and nonautomobile gasoline demand are added, and the seasonal factors are applied to estimate monthly total demand.

Table 5 gives a comparison of actual demand data and predicted values from three of the models recently developed: the Rodekohr, Hartmann-Hopkins, and EIA 1979 Annual Report models. These "backcasts" are calculations made by estimating model parameters over the 1977-1978 period and then using these estimates and actual independent variable values to predict the 1979 monthly gasoline demand. It should be noted that 1979 was a difficult year to predict because of unusual shortages, which caused supply constraints on demand during the summer months. The Rodekohr and 1979 Annual Report models overstate yearly demand by about 6.4 percent, and the Hartmann-Hopkins model understates by about 2.5 percent. The significance of these results is that all of the models predict the downturn in demand, especially late in 1979, after the summer shortage. The mean square error (MSE) and percentage MSE for each model are given below:

Error	Rodekohr Model	Hartmann-Hopkins Model	1979 Annual Report Model
Mean square	0.264	0.094	0.200
Percentage mean square	3.75	1.34	2.84

The results of the performance of the current model for 1980 are given in Table 6. The accuracy of the model can be seen in this backcast. The last three months of "actual" data are preliminary data from the March 1981 issue of EIA's Monthly Energy Review. As the table indicates, the model performs reasonably well. Sources of error include price, income, and fuel-efficiency forecasting errors. Another source of error, of course, arises from the unpredictable nature of consumers' monthly demands. The monthly pattern is monitored continually to reduce error from this source.

The process of model development for short-term prediction of demand for motor-vehicle gasoline has led to a reasonably accurate formulation. In these times of rapid price increases and income fluctuations, the current model is a valuable tool by which to evaluate consumers' responses. It can be used to evaluate the short-term effects on consumption of price controls or gasoline taxes or of mandated fuel-efficiency standards. In addition, given a reasonable projection of pricing decisions by the Organization of Petroleum Exporting Countries and refiners' and distributors' margins, the current model can be used to project gasoline demand. The model, in conjunction with supply information and a balancing system such as STIFS, can be used to signal a surplus or a shortage of gasoline for the nation.

ACKNOWLEDGMENT

We would like to thank Helen Taylor for providing outstanding clerical support in the preparation of this paper. We also thank the staff of STAD and other members of EIA who provided constructive criticism and guidance during the research, writing, and editing phases of the preparation of this paper for publication.

The views expressed in this paper are ours and are not necessarily those of EIA. The paper has not received formal clearance and is provided solely to facilitate discussion of the technical issues it addresses.

REFERENCES

1. Short-Term Integrated Forecasting System Methodology and Model Descriptions. Logistic Management Institute, Washington, DC, Dec. 1979.
2. 1979 Annual Report to Congress. Energy Information Administration, U.S. Department of Energy, Vol. 3, Supplement 1, 1979.
3. Short-Term Energy Outlook. Energy Information Administration, U.S. Department of Energy, May, Aug., and Nov. 1980 and Feb. 1981.
4. 1979 Annual Report to Congress. Energy Information Administration, U.S. Department of Energy, Vol. 3, 1980.
5. Model Documentation Report: Short-Term Gasoline Demand Forecasting Model (ARC '78 Version). Energy Information Administration, U.S. Department of Energy, Nov. 1979.
6. D. Cato. Energy Demand in the OECD Countries. Energy Information Administration, U.S. Department of Energy (in preparation).
7. Data Resources, Inc. The Energy Sector of the DRI U.S. Macro Model. Presented at DRI U.S. Macro Model Seminar, Houston, TX, May 24, 1979.
8. D. Fainer. Price and Income Elasticities of EEC Demand for Petroleum Products. Federal Energy Administration, Oct. 1974.
9. H. Houthakker and M. Kennedy. Demand for Energy as a Function of Price. Presented at American Assn. for the Advancement of Science Conference, San Francisco, Feb. 1974.
10. M. Rodekohr. Generalized Box-Cox Function and the Demand for Petroleum Products. Energy Information Administration, U.S. Department of Energy (in preparation).
11. M. Rodekohr. Demand for Transportation Fuels in the OECD: A Temporal Cross-Section Specification. Applied Energy, 1979.
12. J. Sweeney. Passenger Car Gasoline Demand Model. Energy Information Administration, U.S. Department of Energy, Nov. 1979.
13. S. Wildhorn, B. Burright, and T. Kirkwood. How to Save Gasoline: Public Policy Alternatives for the Automobile. Rand Corp., Santa Monica, CA, Rept. R-1560-NSF, Oct. 1974.
14. D.J. Gantzer. Energy Demand Forecasting in the Transportation Sector. Presented at Operations Research Society of America/Institute of Management Science Joint National Meeting, Colorado Springs, Nov. 11, 1980.
15. The X-11 Variant of the Census Method II Seasonal Adjustment Program. Bureau of the Census, U.S. Department of Commerce, Tech. Paper 15, 1967.

Publication of this paper sponsored by Committee on Energy Conservation and Transportation Demand.

Issues for Developing State Energy Emergency Conservation Plans

MICHAEL A. KOCIS, RONALD H. BIXBY, AND DAVID T. HARTGEN

The key components of the process of developing a state-level energy emergency conservation plan and concomitant issues critical to responding effectively to future fuel-supply emergencies are described. In the event of a declared energy emergency, every state will be expected to consume a certain percentage of fuel below some predetermined base-period volume. The primary concern of the states then is to propose actions to meet the targets during a specified time frame and to achieve objectives such as minimizing market disruptions in geographic subareas and price monitoring. Also of prime concern to the states is maintaining the mobility of the traveling population. Equally important are the equitable distribution of the hardship that results from any shortfall, the ease of implementation of plans in advance of a major fuel-supply interruption, and the reliance on voluntary rather than mandatory conservation by the public. Efforts by the states should assist the public response by emphasizing alternative mobility options and encouraging consumers to find and use those alternatives in their own self-interest.

Since the 1973-1974 oil embargo, both the U.S. Department of Transportation and the U.S. Department of Energy have been increasingly active in transportation energy conservation and contingency planning at the federal, state, and local levels. A clear understanding of the guidelines that have been established and promoted by these agencies during the past years is essential to successful plan development and implementation. Although the effort has accelerated since 1979, the development of adequate plans for energy emergencies has been of great concern only at the local and state levels. In general, these plans can be characterized as a compendium of options that have been inadequately evaluated with respect to their probable effectiveness, their impact on various market segments, and their feasibility of implementation. Furthermore, they are generally not well coordinated with recent federal directives and guidelines on energy contingencies. In an effort to avoid such problems in its own work, the New York State Department of Transportation (NYSDOT) recently contracted with System Design Concepts, Inc., to conduct a fairly extensive study of transportation energy contingency planning. This paper discusses the key components of a planning process and issues critical to an effective response during future energy shortfalls.

BACKGROUND OF TRANSPORTATION ENERGY EMERGENCY PLANNING

U.S. Department of Transportation

The Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) have been promoting a wide range of transportation energy conservation and contingency planning, research,