$ 1.00 *Fall 1973*

EQL Memorandum No. 10

ELASTICITY OF DEMAND FOR GASOLINE IN THE SOUTH COAST AIR BASIN

by Alan M. Schneider
Visiting Associate in Environmental Engineering Science

ENVIRONMENTAL QUALITY LABORATORY

Supported in part by the National Science Foundation Research Applied to National Needs, (RANN), under Grant No. GI-29726

EQL Memorandum No. 10

ELASTICITY OF DEMAND FOR GASOLINE IN THE SOUTH COAST AIR BASIN

by

Alan M. Schneider
Visiting Associate in Environmental Engineering Science

Fall 1973

Supported in part by the National Science Foundation, Research Applied to National Needs (RANN), under Grant No. GI-29726

ABSTRACT

An analysis of California gasoline sales was made, using Box and Jenkins' linear time series methods, in an attempt to detect the change due to a 17% change in price. There was no detectable change within the 2% noise limit of the method. Thus, either the elasticity is less than 2 parts in 17, and/or the tools must be further refined to detect it.

INTRODUCTION

The elasticity of demand for gasoline is the (negative) ratio of the change in consumption per unit change in price. One would like to know this ratio so that one could predict the change in gasoline consumption by the motoring public due to price or tax increases. In particular, such measures have been proposed as part of a total strategy to reduce air pollution in the South Coast Air Basin.

In July and August 1972, a step-function price increase to the consumer occurred in California; a result of (a) an increase in the price charged by the oil producers, and (b) imposition of the 5% state sales tax on gasoline. The price for regular grades of gasoline in the Los Angeles area, which, although subject to a great deal of weekly fluctuation,[+] had been averaging 32.4 cents per gallon,[*] jumped to 38.0 cents per gallon, a 17.3% increase, and remained pretty nearly constant at that level until the end of March 1973.

It was thought that this step increase, if accompanied by a corresponding decrease in sales, would provide data for determining the elasticity, at least for price changes of the indicated amount.

The objective of the present study then is to determine the elasticity of demand for gasoline in the South Coast Air Basin by performing statistical analyses of the data on gasoline sales before and after the price change occurred in an attempt to determine what change in consumption took place.

[+] The Los Angeles market is considered to be an "unstable" one pricewise.

[*] Average over preceding three months at major stations.

It was known from previous studies that the elasticity was small, probably less than 0.1; hence, sophisticated means would have to be employed to extract, hopefully, a small signal buried in heavy noise.

DATA

The data obtained to carry out the study consisted of total taxable gasoline gallonage (less aviation gasoline) sold monthly in the State of California from January 1960 to March 1973 inclusive. The data were obtained from the State Board of Equalization, Sacramento. The agency compiled these figures as part of its task of collecting the tax on gasoline. These data appear as Appendix A.

Price data were obtained as the weekly average for regular grade gasoline of approximately 4,000 major-brand retail stations in the Los Angeles area over the period January 3, 1971—January 28, 1973. These data are compiled regularly as a service to the petroleum industry by the Lundberg Co. The price data were used to determine the magnitude of the increase, which was simply treated as a step function.

It would have been preferable to have had the sales and price data from the same geographic region. As it is, the sales of San Diego, San Francisco, and all other parts of the state are included in the total sales figures. Since the price use at the wholesale level was probably uniform throughout the state, and the 5% sales tax was applied everywhere in the state at the same time, it was felt that the price rise was a step-function in these other areas as well. However, due to the fact that San Diego and San Francisco were historically more "stable" pricewise (less subject to price wars and price fluctuations), the average price in these areas before July 1972 was probably somewhat higher than in Los Angeles. The price in San Diego, San Francisco, and Los Angeles seem to have been more nearly equal and constant after July 1972. In summary, the step-function in price occurred statewide, although the average magnitude for the state as a whole may be less than the 17% experienced in the Los Angeles area.

PROCEDURE

The methods of time series analysis as described by Box and Jenkins (Ref. 1) were used to analyze the sales data. The following assumptions were made:

(1) The time series z_t representing the sales data were the result of a stochastic process in which white noise a_t is the only input (Figure 1).

(2) The stochastic process a_t and linear filter were stationary over the period January 1960 - July 1972.

In particular, assumption (1) implies that the customary weekly 1 to 4 cent price fluctuations prior to the big step of 1972 were inconsequential, and that no other variables ("leading indicators"), such as unemployment rate, were of importance in determining sales. The second assumption implies that the same (unknown) forces were at work to determine sales throughout the entire period. These forces could include growth in car population, growth in per car monthly gasoline consumption, etc. The assumption implies that the increased per mile consumption of new cars with pollution control devices was not a recognizably distinct change in the input process.

The procedure consisted of the following steps:

(1) finding an appropriate form of the model;

(2) estimating the parameters of the model;

(3) diagnostic checking to verify the adequacy of the proposed model;

(4) forecasting the monthly sales beginning with July 1972 with the model, on the assumption that no price change occurred (i.e., the same model applied);

(5) obtaining the standard deviation associated with the forecasts; and

(6) comparing actual sales with forecast sales to see if a significant change in sales, actual relative to forecast, had occurred.

These steps are discussed in more detail in the paragraphs which follow.

Step 1 Finding the form of the model

The time series input data consisted of the 150 monthly sales figures from January 1960 through June 1972 inclusive. These are plotted in Figure 2. As can be seen, there is a strong growth component over the twelve-year period and also a marked seasonality over a one-year period.

The natural logarithm of the data was taken to remove a constant exponential growth factor. The result of this is, by definition, the time series z_t of Figure 1. Then, the first (∇) and twelfth (∇_{12}) backward differences were taken, yielding a time series w_t.*

(1) $$w_t = \nabla\nabla_{12} z_t$$

* Notation follows that of Reference 1.

The mean of the w_t series, $\overline{w}$, was subtracted from w_t, and the resulting time series was fit by a moving average seasonal/non-seasonal model of the form:

$$(2) \qquad w_t - \overline{w} = (1 - \theta_1 B)(1 - \theta_{s1} B^{12}) a_t$$

where

B = backward shift operator, i.e., $Ba_t = a_{t-1}$

θ_1, θ_{s1} = unknown model parameters, to be determined by fitting the model

This particular form of the model was arrived at by first following the preliminary identification procedures for non-seasonal models as suggested in Chapter 6, Ref. 1.

Step 2 . Estimating model parameters

The parameters of the model were determined in each case by the Marquardt algorithm for nonlinear least-square estimation, p. 504, Ref. 1. In essence, that set of parameters is selected which permits the sum of squares of the residuals, a_t in model 2, to be the smallest. The program used to perform the needed calculations was patterned after the estimation procedure of pp. 500-505, Ref. 1.

Step 3 Diagnostic checking

To determine whether the assumed model form, together with its estimated parameters, constituted a reasonable one, having satisfactory stochastic properties,* the residuals a_t, and their first 32 autocorrelations

* Ref. 1 (p. 291) describes the chi-square test as a general, or "portmanteau," test of the hypothesis of model adequacy.

$r_{aa}(k)(k = 1, 32)$, were calculated according to the procedure of p. 503, Ref. 1. The chi-square statistic

(3) $$\chi^2 = n \sum_{k=1}^{32} r_{\hat{a}\hat{a}}(k)$$

was computed where n is the number of data points in the w_t series (n = 150-1-12 = 137), and was compared with a chi-square distribution with

$$\nu = 32 - 2 = 30$$

degrees of freedom, 2 being the number of parameters estimated in the model. Only if the model passes this check do we regard it as in any way being representative of the process which generates the data. (Even if it passes this test, it still may not represent the data.)

Step 4 Forecasting

The time series used the given data up to and including June 1972, and then the model was used to forecast data beginning with July 1972 under the assumption that the model was still valid. That is, the forecast figures are those sales which we would have expected had there been no sudden change in price. The forecasting procedures of Chapter 9, Ref. 1 were used. Forecasts of w_t were converted back to z_t, and the anti-log of this becomes the sales forecast.*

Step 5 Standard deviation of the forecasts

There is an uncertainty in the forecasts which grows as the lead interval (the length of time over which the forecast is made) increases. This

---

* The anti-log of a normally distributed random variable generates a log normally distributed random variable, whose mean is offset from the anti-log of the mean of the former by an amount which depends on the variance. In this case, the offset affects the predicted sales by one part in 5000, a negligible amount.

uncertainty is expressible in terms of the variance V(l) of the forecast for lead time l (l = 1, 2, ... for one-month, two-month, etc., forecasts). The standard deviation of the forecast at lead time l is the square root of the variance. The model itself provides the basis for estimating the variance of the forecasts.

Step 6 Comparison of actual and forecast sales

The forecast sales are those which we expect if there had been no change in conditions, i.e., if the same model (2) with its estimated parameters applied. If the actual sales differ significantly (say more than 1, 2 or 3 standard deviations) from the forecast values, then we can say that the time series analysis has detected a change in consumption. The ratio of the change in consumption (expressed in percent) to the change in price (also expressed in percent) is the elasticity.

RESULTS

As discussed above, preliminary estimation procedures led to selection of model (2) as the working hypothesis.

The diagnostic check for model (2) gave an observed chi-square of 30.0 for 32 residual autocorrelations and 30 degrees of freedom. The 50% and 25% points for model (2) with 30 degrees of freedom are 29.3 and 34.8 respectively. Therefore, the check does not give any evidence of the inadequacy of the model. The estimated parameters of the model are:

$$\theta_1 = .95367759 \pm .0301$$

$$\theta_{s1} = .97947884 \pm .0070$$

The data do not warrant the inclusion of all of the digits produced by the computer; however, results are given as generated rather than introducing roundoff. The plus-minus figures are the standard deviation of the estimates.

The model (2) selected gave better results than any of the following, which were also tested.

(4) $$w_t - \bar{w} = (1 - \theta_1 B)(1 - \theta_{s1} B^{12} - \theta_{s2} B^{24}) a_t$$

(5) $$w_t - \bar{w} = (1 - \theta_1 B - \theta_2 B^2)(1 - \theta_{s1} B^{12} - \theta_{s2} B^{24}) a_t$$

(6) $$w_t - \bar{w} = (1 - \theta_1 B - \theta_s B^{12} - \theta_{s+1} B^{13}) a_t$$

(7) $$(1 - \Phi B^{12})(w_t - \bar{w}) = (1 - \theta_1 B - \theta_s B^{12} - \theta_{s+1} B^{13}) a_t$$

The forecasts obtained with the model (2) are shown in Figure 3. The latter figure also shows the one-sigma tolerance on the forecasts and the actual sales. The one-sigma tolerance, expressed as a percent of sales, varied from 1.99 for the 1-month lead (the July forecast) to 2.01 for the 9-month lead. This tells us, essentially, that the assumed model, and the data it was fitted to, together were capable of detecting changes in sales of about 2% but that changes in sales of less than this amount would be buried within the still-remaining model noise.

Comparing the actual sales (with the price increase) to the sales forecast on the basis of no change in price, it is seen that the differences still lie within the noise band of the model. Thus, it is not possible, from the analysis performed, to know whether a change in sales level occurred or not when the price rose 17%.

CONCLUSIONS

It is not clear that the increase in price in the Los Angeles area of 17% produced any observable change in gasoline consumption in the state. If there was a net change in sales, it was less than 2%, the noise limit of the present analysis.

It must be recognized that a 17% increase in price in gasoline represents probably no more than a 3% increase in the cost of operating a car, and just a few tenths of a percent of total average income. Thus, small changes in gasoline price may not show the same elasticity effects as large changes. Also, the present study looked for short-term response, whereas long-term adjustments may be more significant.

RECOMMENDATIONS

If one were interested in carrying the analysis still further, in an attempt, for example, to reduce the noise level on the forecasts (and to improve the forecasts in the process), then the following should help.

(1) Obtain data on both price and sales for the same geographic region.

(2) Include in the formulation a linear dynamic system which represents a deterministic dependence of the model on price. For even better results, include other factors which are believed to have a significant effect on gasoline consumption. One such factor would be the decreased miles per gallon realized with the newest model cars. This, of course, requires complete price data over the same time period as the sales data. Another factor to include might be some prosperity indicator, or negative prosperity indicator (unemployment rate in the area) which presumably would have some influence on gasoline

sales. Then the model becomes the multiple-input model shown in Figure 4. Methods for analyzing such models are a direct extension of the methods applied here, and are discussed in Chapter 11 of Ref. 1.

(3) Continue the analysis as time progresses. As this is being written the price is climbing at an accelerated pace.

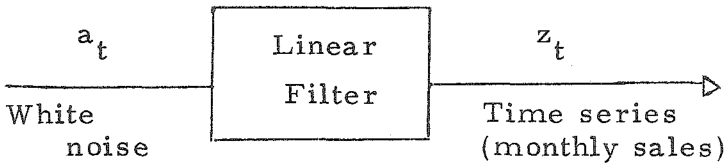


Figure 1
The Stochastic Process

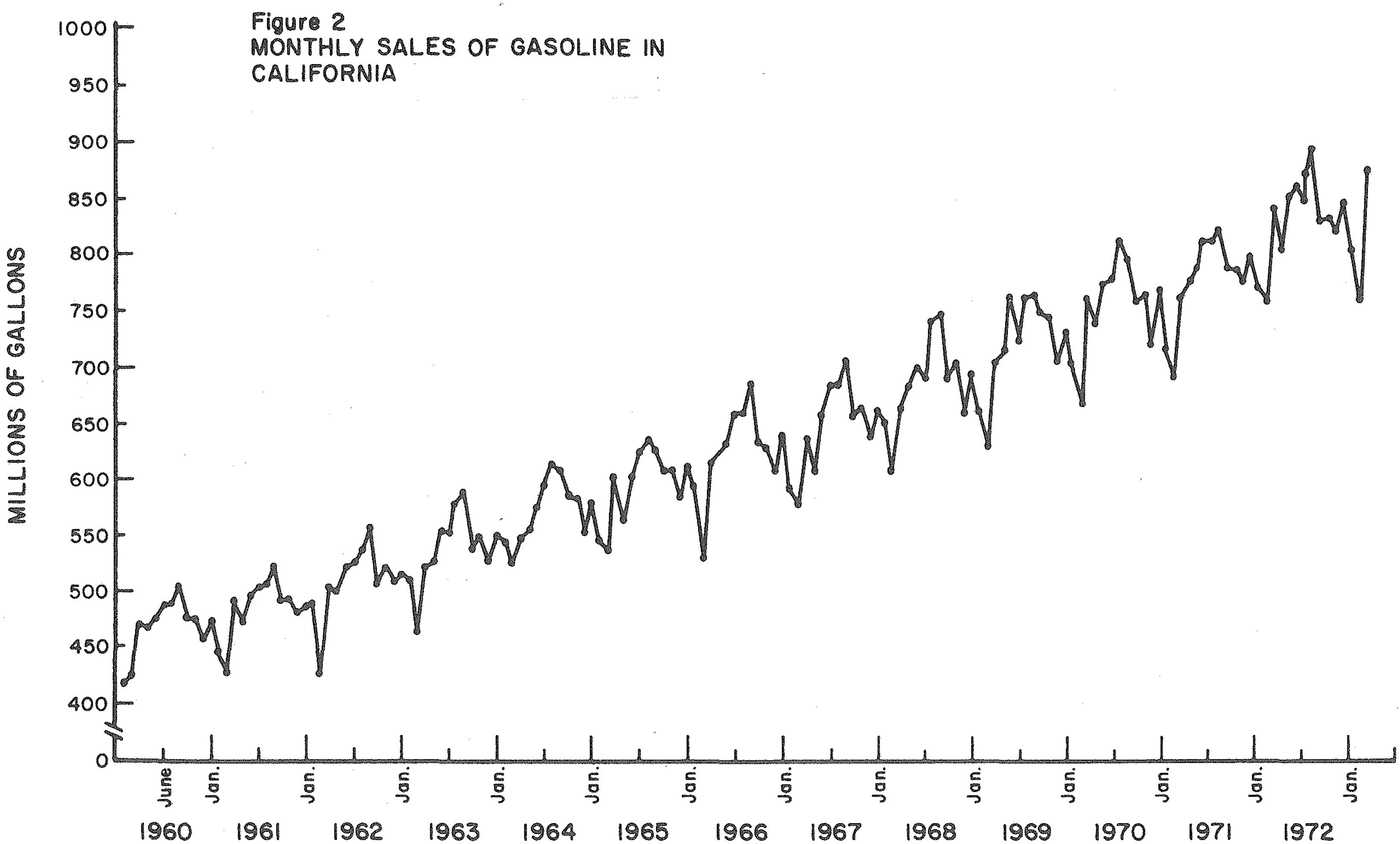
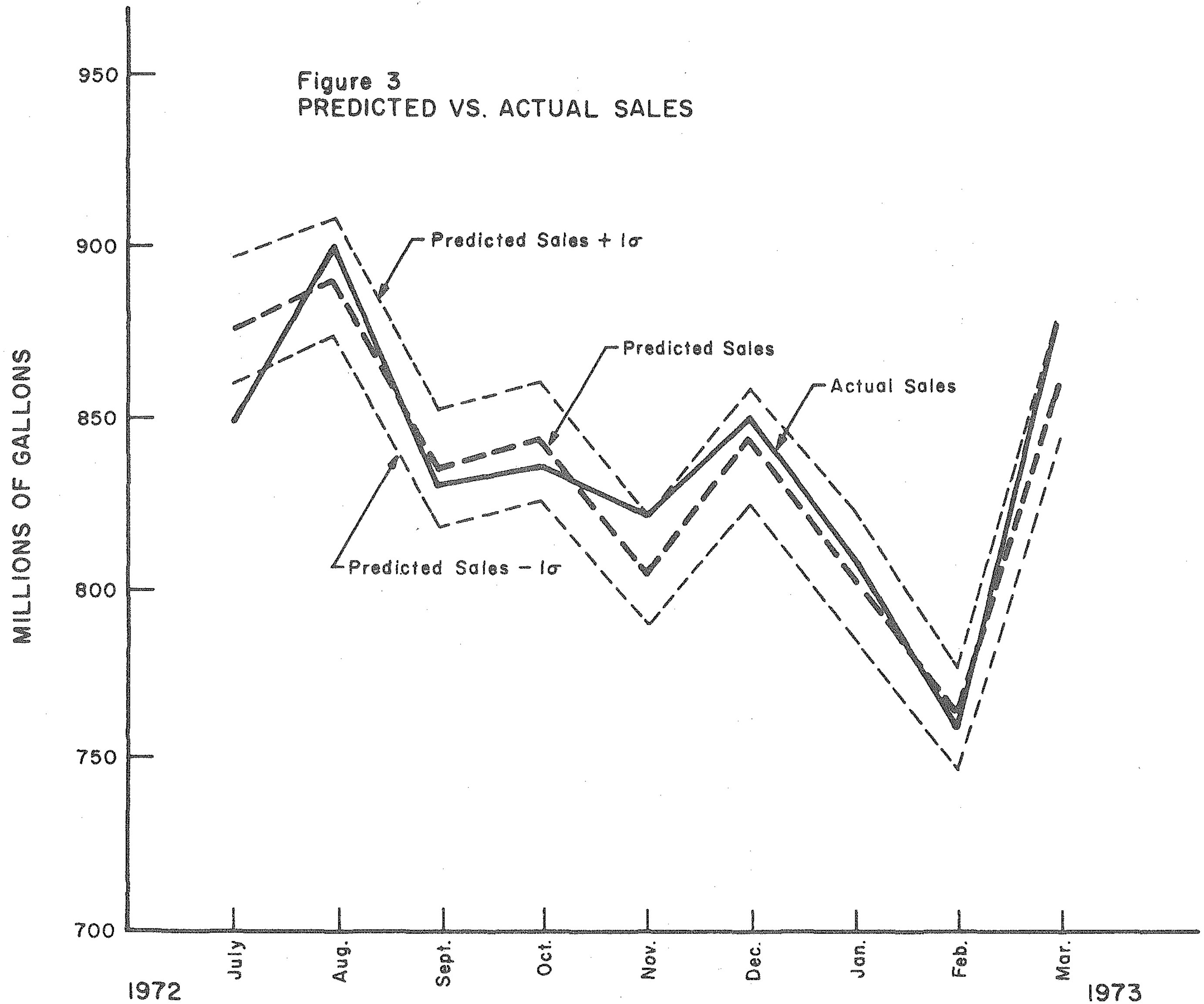


Figure 2
MONTHLY SALES OF GASOLINE IN CALIFORNIA
MILLIONS OF GALLONS
1000
950
900
850
800
750
700
650
600
550
500
450
400
0
June
Jan.
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972

Figure 3
PREDICTED VS. ACTUAL SALES



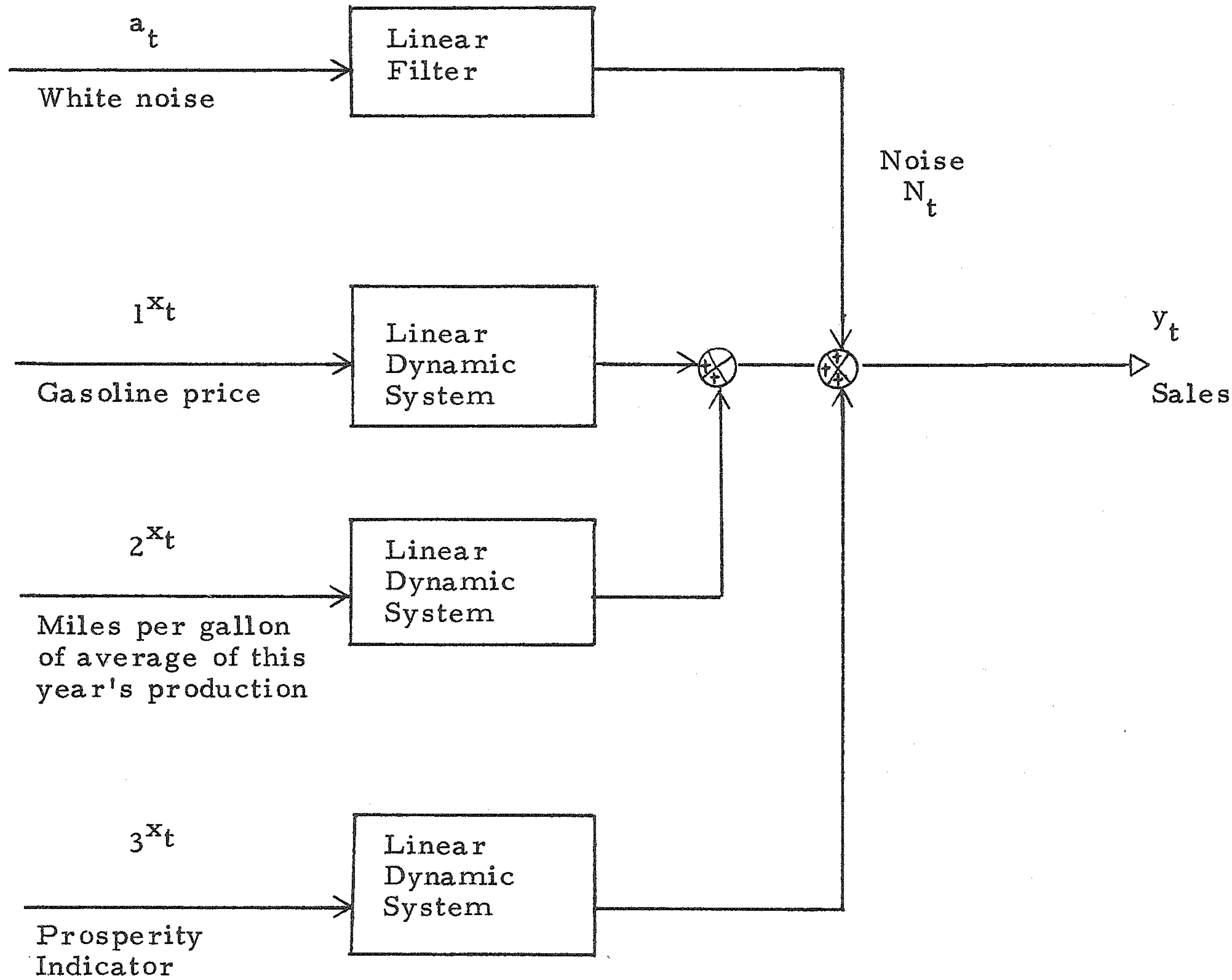


Figure 4

Multiple-Input Deterministic/Stochastic-Model

REFERENCE

1. Box, George P., and Gwilym M. Jenkins, Time Series Analysis, Forecasting, and Control, Copyright 1970, Second Printing 1971, Holden-Day, San Francisco.

APPENDIX A

Total Monthly Gasoline (less Aviation) Sales in California (Gallons)

January 1960 - March 1973 Inclusive

419525966	426648441	471355767	468579504	476871751	488728081
490443236	509990974	476570597	473323177	457312473	476025319
448176905	424021439	494401792	470221431	499261765	505011073
507760806	525805876	492905287	493830971	480675775	488444300
479157595	426691513	507608741	499951034	522575859	526863764
537756552	560099067	505188157	527819708	508842006	518388590
512513491	462678605	523365025	529412632	554244136	552311172
580935092	592866525	538805405	552373267	527487962	551953739
543969522	527299671	549272767	555980663	574400274	599626856
615948480	608705525	588011227	582087772	548347603	586726967
544401794	531359326	605921762	560788840	605382754	624020730
639228416	629159189	608954524	608790856	580213242	615355004
593413574	528548553	619203521	625405286	636973982	659434045
659462378	689180380	631606786	628412744	604798619	641171006
593278660	573680460	639718321	602921336	657360979	684601313
683354587	708990207	654237227	668952664	632059576	666182877
650302605	606857777	666110515	686603193	702221786	688027598
740879137	747311910	689125677	707951626	658555091	696850990
661497199	628947871	706965083	715861781	768411771	722660760
765914293	764888787	750609087	747916545	705170400	733540728
704161429	667839557	764958389	739530638	774130469	779636361
814846854	798427743	758250071	766100930	721869531	771607070
717759909	692579960	765440919	777442698	789538807	815086188
817775618	822949774	790058781	788992405	779558984	801108894
771559455	758301373	845233081	806046434	856752072	866595658
847761632	899385235	831569009	836898326	822385628	852003692
809773370	760666260	879012700			

Note: Read horizontally, then down one row at a time.