THE DESIGN OF A REFINED PRODUCTS DISTRIBUTION SYSTEM

by

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CHAPTER I

INTRODUCTION

There are very few manufacturing concerns which enjoy the position of having customers come to their factories to purchase products. Some type of distribution system must exist in order to get the products into the hands of the customers, through final sales outlets. In highly competitive product areas these distribution systems are of greater importance, as the customer looks not only for a quality product, but also for service and convenience in purchasing. Even a company enjoying a monopolistic position would require some means of distributing its products if its marketing area was of any considerable size. Distribution systems exist in varying degrees of complication and sophistication, depending on the industry, the company, and the particular product. The numerous storage, handling, and transportation operations taking place between factories and final sales outlets may contribute greatly to the cost of a product. Planning and coordination of these activities for efficient operation requires the solution of production scheduling and inventory control problems, choices of alternative equipment, selection of plant and warehouse locations, and numerous other applications of the methods of management science.

Problems encountered in petroleum operations are somewhat unique due to the fluid property of the raw materials and most finished products. Crude oil stocks and finished products are often easier to transport, and can be handled by relatively continuous processes which introduce certain economies in transportation yet create special
problems in production scheduling and inventory control. Greater inter-
relationships exist between the various functions of exploration and
production, refining, and marketing than are found in most other manu-
facturing operations, as will be seen in the following brief discussion
of petroleum operations. Because of these interrelationships, the ef-
fects of changes in any company function are more evident throughout
the rest of the operations than with industries whose various activities
are more discretely separated.

Most crude oil stocks are produced in areas remote from the major
demand. The production of crude can be scheduled by linear programming
techniques so as to minimize the cost of meeting the requirements of the
refineries for quantities of specific types of crude within restrictions
imposed by equipment capacities and the production rates allowable by
government regulation and physical pumping phenomena. The crude oil
removed from the earth is collected in gathering systems from the in-
dividual wells and transported to the refineries through extensive,
specialized facilities: pipelines, tank trucks, railcars, tankers, and
barges. For a required slate of finished products, some crude types
are more desirable or profitable to refine than others. It is common
for an oil company to exchange crude oil at a given location for the
crude of another company, either because of economics of transportation
or more desirable properties of the other crude. The evaluation of
the profitability of the exchange of a proprietary crude for another
company's crude, given the configuration of refineries and associated
economics of transporting and processing one crude rather than another
can be carried out through the use of linear programming (Wagner 11, 59).
Some refineries run the same feed stock blends continuously, creating the same products all the time. Others vary the feeds to get different product mixes, as changes in demand require adjustments in operations. For example, a greater demand exists for fuel oils in winter, while gasoline demand peaks in summer. As flows of crude oil and refined products cannot be exactly synchronized with market demands, problems of inventory control of feed stocks and finished products arise as well as production scheduling problems. These problems are further complicated by limitations on the maximum and minimum amounts of each product obtainable from the available crude, i.e., there is a maximum amount of gasoline which may be refined from a barrel of crude oil, and in refining this gasoline there is a minimum amount of fuel oil which will result due to the composition of the crude and the limitations of refining process technology.

These problems have yielded to various techniques of mathematical programming. Linear programming formulations are widely utilized in the selection and blending of crude stocks to be refined to meet product demands within crude availability and equipment throughput restrictions. This planning of weekly or monthly minimum cost production schedules for refinery unit operations must also consider the range of performance characteristics of the resulting products. Many refined products may be blended from basic stocks to obtain required quality characteristics such as vapor pressures and octane ratings. In the case of octane ratings, the quality varies nonlinearly with the amount of tetraethyl lead added to the mix, a smaller octane rating increase
resulting from additional increments of "lead" added. Blending the basic stocks to obtain a desired slate of final products is thus a nonlinear programming application, which has been solved using linear approximations and an iterative linear programming technique known in the industry as "recosting." Not only have some companies combined the two previous mathematical programming problems into one model, there have been attempts to "optimize" the scheduling of all of a company's refineries simultaneously, given certain marketing goals. A more generally used analysis also involving mathematical programming is the evaluation of exchange agreements with other companies for final products, analyzed in similar manner to the exchange of crude stocks previously discussed.

While products such as greases, lubricating oils, and special chemicals are packaged in discrete quantities for storage and shipment, the motor fuels, distillates, and petroleum gases may be held in large tanks for future demand and eventual shipment, or transferred directly to the final sales outlet. There are several alternative modes of transportation for refined products which presents another problem. Products must be routed from various refineries to a number of marketing areas using the least cost mode of transportation recognizing factors of differentials in costs of manufacturing products at these various refineries, shipping costs, and the seasonal variations in consumer demand for the refined products.

Pipelines are generally the cheapest transportation method for high volume shipment of products. The pipelines also require a higher initial cost to build, thus a number of companies often share a pipeline,
each having refineries on the line. Several products may be shipped through a given pipeline thus creating problems in pipeline scheduling. Various considerations of pipeline scheduling include determination of optimal storage tank sizes and optimal shipment quantities, as well as the timing of the shipments. Usually there are several bulk stations along a given pipeline where the products are removed and stored in anticipation of future demand. At these points, products may be transported to final sales outlets or shipped to other intermediate storage facilities.

The use of barges and tankers to ship refined products is common to refineries located on waterways. Many oil companies own fleets of tankers and barges rather than hire common carriers. Tanker and barge scheduling problems are as difficult as pipeline scheduling. Given a fleet of vessels, a company has to set a timetable for each vessel in order to meet all the demands for products. Considerations must be given to storage facilities at the source and destination as well as to the maximum utilization of the vessels.

A fully integrated oil company produces a wide range of products: natural gas, gasolines, kerosene, fuel oils, chemicals, lubricating oils, greases, waxes, asphalt, fertilizer, synthetic rubber, plastic resins, and even synthetic fibers. The most familiar products include the distillates and motor fuels, however. It is the specific area of motor fuel distribution that will be researched herein, and the discussion will continue in this context, although most comments may be extended to other products. Highly competitive conditions usually
exist in gasoline marketing; there are a lot of promotional efforts, advertising, and price wars. Further, the industry is faced with rising labor costs, higher crude prices, and more recently, increased manufacturing costs for low lead and lead free motor fuels. All of these factors call for improved operational efficiency.

Distribution systems for motor fuels exist in varying degrees of complexity from one company to another, complicated by the fact that most oil company final sales are handled through jobbers as well as company owned stations. At a given terminal, a company usually has its own fleet of vehicles, which delivers the motor fuels to the service stations of jobbers and company owned stations. In many instances, however, jobbers own trucks and receive their stocks of motor fuels at the bulk terminals. The company may also serve independent distributors from a terminal, as well as other major oil companies by exchange agreement.

The operational policies of most companies have developed over the years largely from the experiences of the people most directly involved in the day to day operations. Thus a wide range of variation is found in the operating procedures of different bulk terminals. A given set of procedures may vary within the industry, within a company, and even within a sales district.

The method of payment for a shipment of products may be on consignment, cash on delivery, 90-day credit, or a number of other policies. For a company selling to dealers on a consignment basis, a typical situation involves the periodic reading of pump meters by a company representative who reports his readings to a sales office. The
required amount of product to be delivered is then calculated and the billing and ordering processes are carried out, the station being billed for the previous volume sold. The terminal dispatcher is given a manifest each day of the required deliveries, and he assigns vehicles to make the drops. This scheduling and routing of deliveries is normally based on the experience of the dispatcher.

Of course there is a lead time involved in the ordering process between the reading of the pumps and the actual delivery. During this time stockouts may occur, as most often there is little consideration given to setting safety stock levels. The company representatives merely make their visits at specified intervals, taking orders for the various products, and in some cases auditing the station. The resulting order sizes may vary greatly, no optimal order size having been set.

Another widely used procedure is that in which each station manager orders a new supply directly from the terminal. He may or may not have been told when to reorder, in terms of a reorder point. This policy often is associated with cash on delivery sales. Of course, the station managers will then order only when they feel they can pay, or may tend to order smaller quantities so they do not have to release large amounts of their cash. This policy creates an excess of emergency situations, when station managers wait until the latest possible minute to order, and then need to be supplied right away to avoid run-out. Generally the deliveries for a particular day are not known well enough in advance to efficiently plan the routes of the delivery vehicles.
With the availability of various analytical techniques, it is now possible for an oil company to examine the procedures for operating a distribution system and improve the operations. Within the distribution system composed of a bulk terminal and all service stations served by company owned vehicles from that bulk terminal, there are several areas in which research may yield improvement in operations. The stimulus that sets this distribution system into action is consumer demand, a variable beyond control to a large degree except through promotional efforts. Thus, it is highly desirable to develop information about demand patterns, with regard to average demand rate, growth trends, seasonal effects, and random day to day fluctuations, as these factors directly affect the safety stock levels and economic order quantities, thus affecting order frequencies. The logical starting point for any system improvement would then be to examine and analyze past data to determine the factors affecting the pattern of demand. If the components of the demand patterns can be identified and quantified, the proper forecasting model can be developed. This leads the way to inventory control studies, a logical objective of which is to set safety stock levels and reorder points at each station. An inventory control study would also result in determination of economic order quantities and order frequencies.

In consideration of the pertinent costs in the inventory study, stock out costs (opportunity costs), ordering costs, and inventory carrying costs would be straightforward. Transportation costs, however, would be difficult to consider as the efficiency of dispatching vehicles depends not only on the routing schemes but on the size of orders (full loads or fractions). Although much research has been done on developing vehicle
routing algorithms, most of them are difficult to apply to dynamic and/or probabilistic situations. The more practical routing algorithms developed to date are based on heuristic methods, and do not guarantee an optimal solution to a given problem (Cochran 3; Tillman 10). In determining a routing scheme with these proposed techniques, the description of the fleet of vehicles available at the terminal is required as a restriction in the development of routes. Information on the number of vehicles, size of each, and size of compartments is required. These programs could easily be run with varying fleet descriptions to simulate alternative equipment specifications in an effort to find the best combination and number of vehicles.

Evaluation of bulk terminal loading equipment and procedures is another area for improvement. With the demands on a terminal given, design of loading facilities to serve this demand can be analyzed through simulation (Collins 4). This type of study generally includes the examination of alternative arrangements of assigning products to loading racks, number of racks required, as well as the number of spouts on each rack. The normal considerations of equipment specifications, pump sizes and storage tank sizes are evaluated concurrently. These alternatives are aimed at changing the service time distribution. A less obvious, nonetheless important consideration is the possibility of altering the customer interarrival time distribution. This would be more feasible and more effective in situations where a larger per cent of a terminal's volume is delivered by company owned vehicles. The servicing of demands with these vehicles could very well be shifted to night or periods when the terminal is not overloaded.
1.1 Problem Definition

Within the time restriction, the scope of this thesis cannot embrace all of the above enumerated problems. Therefore attention is focused on the smaller segment of the distribution system consisting of a bulk terminal and all of its facilities, including the fleet of vehicles at that terminal, and the company owned service stations served from the bulk terminal. Each service station is assumed to sell only two products, regular and premium gasolines. Although other products such as diesel fuels and non-leaded gasolines may be sold at a station, these products are not considered directly. The proposed analysis for the two motor fuels can be extended to include other products, however.

The data provided for this thesis includes actual daily gasoline sales volumes for regular and premium sales from a major petroleum company, for two consecutive years, beginning on December 26, 1966 and extending to December 29, 1968. All of the stations operate seven days a week. The figures are taken from detailed audit computer listings as provided by the company's controllers department. A sample of twenty-five company owned stations located in the same marketing area, all served by the same bulk terminal is used. The sample excludes the jobber owned stations. An area where good district sales management had been practiced was selected by a company sales department technical analyst. Areas where abnormal competitive conditions had existed were avoided. In addition the area was selected because it gave a good cross section of the various site types: residential, shopping center, interstate, and business district. The area itself was not revealed, as this
information would expose the company's competitive position in that area. The Tulsa area has been assumed by the author, and station locations are placed on the Tulsa map in accordance to actual station locations where possible. The bulk terminal is assumed to be located at an actual refinery location in Tulsa (not belonging to the company supplying the data). From this hypothetical station distribution, the interstation distances and travel rates are estimated using the most reasonable routes between the points. The travel times are then calculated from this information. The rates, thus the times, are assumed to be constant with regard to time of day. Table 1.1 displays the rates, distances and times. Each station is identified by site type, and the storage tank capacities for each product are given. This data is presented in Table 1.2.

Uniform operating hours for all stations are assumed, with no preferential delivery times. A consignment sales policy is assumed, as this is the only policy which allows the company to deliver at its own convenience. Under this policy the company bears the costs of carrying inventory, including leakage, evaporation, and theft from the tanks. The costs of the products at the terminal are given, and are assumed to be constant with respect to time and order quantity. Estimated inventory carrying cost is also given. Stock out costs are not available.

The bulk terminal is assumed to have a sufficient supply of product to meet all demand. The cost of operating 8000 gallon tank trucks is given in terms of drivers' hourly wages, yearly costs of taxes and licensing, and the operational and maintenance costs per mile driven. The total daily availability of the vehicles, shift lengths, number of
shifts per day, and total allowable overtime are investigated. The vehicles are assumed to have two compartments for one case, the industry range being from 2 to 6 compartments per vehicle. The sizes of the two compartments are variables to be investigated in the study. As another alternative in the simulation, separate delivery of each product is also to be investigated (non-compartmentalized vehicles). The terminal is assumed to operate 6 days a week. In actual practice periods of terminal congestion may occur due to queueing at the loading facility. This would add an additional time variable, vehicle waiting time, which would be from some distribution dependent upon time of day. Since this information is not available, instant service is assumed, with a constant time assumed for each truck loading of 15 minutes, during which time the vehicle is positioned at the loading facility, set up for loading, and the delivery manifest prepared. A loading rate of 400 gallons per minute is given and used to determine a variable loading time dependent on the volume of product being loaded. Likewise for each delivery a constant time of 15 minutes is assumed, with a given unloading rate of 450 gallons per minute used to determine the variable unloading time.

In the case of the emergency order situation, the orders are assumed to be expedited. In the real situation, there is a chance of a stockout at a station placing an emergency order if a vehicle were not immediately available. As the demand distributions on smaller time scales are not known, it is not possible to express the probability of this stockout, nor the expected number of gallons of lost sales. The
normal waiting time, however, is known to include waiting time for the availability of a vehicle plus loading time plus travel time. The company supplying the data reported a normal order lead time of 1 day for gasoline orders, with about 25% of the orders being placed on the day delivery was required.

All information assumed by the author had been discussed with a member of the operations research staff of the company to verify the reasonableness of the assumptions. The cost information and other given information is summarized in Table 1.3. The time series themselves are too lengthy to be presented.

1.2 Proposed Research

Within the distribution subsystem defined in the previous section, there are several possible areas for operations improvement. Decisions in this area are confined to shorter range problems for the most part, generally those dealing with delivery scheduling and inventory control. Some type of inventory control policy always exists for any system where stocks of products are needed to meet demands, by default if not established. In this case these policies are rough rules of thumb, a popular rule being to keep stock levels above 25% of tank capacity. This level is not arrived at strictly from inventory considerations, but because of water and dirt accumulation in the storage tanks. Mathematical derivation of an inventory model is not an objective of this research, as there is known to exist a complicated relationship between the delivery scheduling and inventory policy. In a mathematical inventory model, there should be a term reflecting the cost of delivery of
various size orders, considering the probabilistic nature of the demand during delivery lead time, as well as the costs of transportation when deliveries to more than one location are made on a single route. This indicates the interaction among the station locations considered in overall distribution planning. In determining order sizes independently for each station, the optimal order size for a given location may be less than a full truck load, however there may not be enough remaining vehicle capacity to deliver the specified order quantity to another station. An optimal reorder policy would consider the overall effect of reducing one or both of the quantities to allow for better vehicle utilization, and then give an order size minimizing the total system operating cost. The effect of reducing the order size below that derived considering each station independently would be an increase in order frequency. Again, the model would be further complicated if the probabilistic nature of a station's actual requirement were considered. Thus it is evident that some coordinated ordering procedure among the stations is needed, which balances the costs of carrying inventory and order placement against the conflicting costs of vehicle utilization.

In addition, the problem of demand variability with a growth term and seasonal effects would prevent any simplifying assumption of constant demand, without badly distorting the results. Thus some other approach is desired. Simulation is felt to be the most practical approach. Reorder levels are to be assumed and, attention focused on the scheduling considerations, with effects on the inventory system examined. Factors for reduction of order sizes are to be examined, as well as vehicle compartment sizes simply by case study. The actual arrangement
of stations on routes has already been researched, and several algorithms are available to facilitate the routing. A modified Clarke and Wright procedure (Cochran 3) is chosen to model the routing or dispatching process, extended to accept compartmentalized vehicles and consider order size reduction. This algorithm has proven to be reasonably fast computationally and gives good results.

In order to examine any of the alternatives to delivery planning and order actuation, it is first necessary to develop a demand modeling procedure to provide a simulated demand process to the inventory-delivery simulation. This comprises a significant portion of the research.
### Distance Matrix

|   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 6   | 11  | 16  | 21  | 26  | 31  | 36  | 41  | 46  | 51  | 56  | 61  | 66  | 71  | 76  | 81  | 86  | 91  | 96  | 101 | 106 | 111 | 116 |
| 2 | 6.9 | 11.9 | 16.9 | 21.9 | 26.9 | 31.9 | 36.9 | 41.9 | 46.9 | 51.9 | 56.9 | 61.9 | 66.9 | 71.9 | 76.9 | 81.9 | 86.9 | 91.9 | 96.9 | 101.9 | 106.9 | 111.9 |

### Rate Matrix

|   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 20  | 25  | 30  | 35  | 40  | 45  | 50  | 55  | 60  | 65  | 70  | 75  | 80  | 85  | 90  | 95  | 100 | 105 | 110 | 115 | 120 | 125 | 130 |
| 2 | 25  | 30  | 35  | 40  | 45  | 50  | 55  | 60  | 65  | 70  | 75  | 80  | 85  | 90  | 95  | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 |

### Table 1.1
|    | 0.3 | 0.2 | 0.1 | 0.4 | 0.3 | 0.2 | 0.2 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 0.3 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 |

**TABLE 1.1 (continued)**
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<th>TYPE</th>
<th>STORAGE TANK CAPACITIES</th>
</tr>
</thead>
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<td></td>
<td>REGULAR</td>
</tr>
<tr>
<td>1</td>
<td>Residential</td>
<td>8000</td>
</tr>
<tr>
<td>2</td>
<td>Residential</td>
<td>6000</td>
</tr>
<tr>
<td>3</td>
<td>Interstate</td>
<td>12000</td>
</tr>
<tr>
<td>4</td>
<td>Shopping Center</td>
<td>8000</td>
</tr>
<tr>
<td>5</td>
<td>Interstate</td>
<td>8000</td>
</tr>
<tr>
<td>6</td>
<td>Interstate</td>
<td>8000</td>
</tr>
<tr>
<td>7</td>
<td>Interstate</td>
<td>12000</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Shopping Center</td>
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</tr>
<tr>
<td>10</td>
<td>Business</td>
<td>8000</td>
</tr>
<tr>
<td>11</td>
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<td>8000</td>
</tr>
<tr>
<td>12</td>
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<td>8000</td>
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<td>Business</td>
<td>8000</td>
</tr>
<tr>
<td>14</td>
<td>Residential</td>
<td>8000</td>
</tr>
<tr>
<td>15</td>
<td>Shopping Center</td>
<td>8000</td>
</tr>
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<td>Residential</td>
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</tr>
<tr>
<td>25</td>
<td>Shopping Center</td>
<td>8000</td>
</tr>
</tbody>
</table>

**TABLE 1.2**
COST INFORMATION GIVEN

Drivers' wages $3.50/hour
Cost of regular gasoline at the terminal $.11/gallon
Cost of premium gasoline at the terminal $.12/gallon
Costs associated with 8000 gallon vehicles:
  Purchase price $36,000.00
  Taxes, licenses, and insurance $1,200.00/year
  Maintenance costs $.135/mile
  Operating costs $.16/mile

FLOW RATES

Loading rate 400 gallons per minute
Unloading rate 450 gallons per minute

TABLE 1.3
CHAPTER II

DEMAND ANALYSIS AND MODELING

2.1. Objectives

The first phase of research deals with the application of methods of time series analysis to the historical sales data in an effort to develop demand models. These models are needed to provide daily demands for each of the two products at the twenty-five station locations as inputs to the delivery scheduling and routing routines of the simulation. A thorough analysis of the past data is required to establish these models with the degree of accuracy necessary to obtain valid results from the simulation. Demand modeling is a preliminary step in forecasting future gasoline sales, however forecasting is not an objective of the study. In producing forecasts, adaptive fitting would be required to allow the model coefficients to be modified in response to changes in the underlying demand generation process. Testing any adaptive fitting schemes would require longer series of data than are available, as the smoothing coefficients should be selected and tested over a separate segment of the time series from that used in establishing the basic models.

The objective is to arrive at some compact form of expressing the demand patterns present in the raw data, preferably through models which may be used iteratively in obtaining daily sales. This is necessary to avoid storing the actual sales histories in the computer. Such a large amount of data would require the use of external storage, and accessing the data would greatly slow the simulation. Further, it is hoped that
a few model types will be sufficient to describe the processes; that enough similarity exists among some of the stations' demand patterns that they may be classed into groups. The immediate questions arising are the existence of similarities in demand patterns among the stations within each of the four site type classifications, and the presence of correlation between regular and premium sales.

2.2 Model Types Considered

The models considered are limited to time series models rather than correlational models. This is due primarily to the availability of data, with only historical sales data obtainable. There is no guarantee that correlational models would be more accurate; further, there are many possible independent variables to be considered. Some of the possible factors include weather information, traffic counts, competitive price differentials, station area demographics, and other econometric considerations. If the data were available for establishing these types of models, there would remain a problem of predicting the independent variables if they were not related to sales as leading indicators. Promotional effects of competitors and weather are obviously difficult, if not impossible to predict, and their effects would likely be immediate. Further, Brown (1, 77) warns that two time series, each having a significant autocorrelation function, are very likely to show a strong cross correlation. It should be justified from an economic point of view that one independent variable could affect the dependent variable before it is used.
Within time series analysis, the objective is to determine the presence of trend, cyclic, and seasonal components of demand fluctuation, all being expressible as functions of time only. The significant components should adequately account for the variations of the time series; the unexplained variation should be random, with a mean of zero. More specifically, the terms considered for use in the models herein include polynomials, exponentials, and trigonometric terms (sines and cosines).

2.3 Analytical Techniques of Time Series Analysis

The determination of the various components of a time series can be difficult, particularly with regard to cyclic variations, where one or more may be superimposed upon another. There are diagnostic tools available which are aids in determining not only the presence of cyclic variations, but the relative importance of each cyclic element's contribution to the total variation of a given time series.

2.3.1 Fourier Analysis

The theory of Fourier analysis forms the basis for time series analysis by sine and cosine terms. Fourier developed the principle that a reasonable periodic function of time could be represented on a closed interval with a sufficient number of terms from the series:

$$\xi = C + A_1 \sin \frac{2\pi t}{p} + A_2 \sin \frac{4\pi t}{p} + \ldots + A_k \sin \frac{2k\pi t}{p} + \ldots$$

$$+ B_1 \cos \frac{2\pi t}{p} + B_2 \cos \frac{4\pi t}{p} + \ldots + B_k \cos \frac{2k\pi t}{p} + \ldots$$

(Brown 1,70)
The inclusion of both a sine and cosine term for each periodic term allows a shift in the origin of the sinusoidal effect. This shift is represented by the phase angle $\alpha$, where, for a given pair of periodic terms, $\alpha = \text{arctan} \frac{B_1}{A_1}$, and the amplitude of the effect is expressed as $\alpha = \sqrt{A_1^2 + B_1^2}$ (Brown 1,68). If the sine term were in the model alone, it would have zero effect at the actual origin of the time series. If the cosine term were in the model alone, it would have its maximum effect at the origin of the time series.

The terms in the Fourier Series are harmonics of the basic period $P$. This period is of the maximum length which may be observed in the given time series, that is, at least one full cycle occurring. Harmonic analysis, then, is the procedure of determining the principle harmonic elements of a given time series, where any harmonic element is of a period length which is an integral divisor of the basic period. The goal of harmonic analysis is not to fit a Fourier series to the data, but to determine which periods are present in the data and the relative contribution of each periodic variation to the overall variation of the time series.

Spectral analysis is similar in concept, however has greater flexibility than harmonic analysis in that the importance of all cyclic variations over a given range of periods may be determined. Spectral analysis can produce indications of significant contributions from cyclic variations with periods having no economic meaning. There is no guarantee that these fluctuations would continue into the future, thus care should be exercised in including them in a proposed model.
2.3.2 Use of a Diagnostic Computer Program

The analysis of the cyclic components of the data is performed using a set of subroutines originally designed for spectral analysis in conjunction with linear regression. The difference between spectral analysis and harmonic analysis throughout the remaining discussion is with regard to the type terms considered for inclusion in the models, strict harmonics with harmonic analysis, and any justifiable terms with spectral analysis.

The general procedure for either analysis is merely that of building a model by regression analysis in steps, using information provided by autocorrelation and spectral density plots in determining if the model is sufficient, and if not, what additional terms should be included. At each step, the usual criteria are applied to the results of the regression analysis to judge the quality of the fitted model. The value of $R^2$ is an indication of the portion of the variation of the time series about its mean which is explained by the proposed model. The $F$ ratio indicates the ratio of explained to unexplained variation, and must exceed a predetermined critical level for a specified significance, with appropriate degrees of freedom. The standard error of estimate, the square root of the variance about regression, is required to be less than a specified percentage of the mean of the time series. Draper and Smith (5) is recommended for further detail on regression analysis.

In using the spectral analysis routines, the data must first be detrended. Any significant trend would distort the results of the
spectral density plot, as it would be confused with some long term
cyclic variation exceeding the length of the observed time series. The
trend should then be the first term submitted to the regression analysis.
From the regression analysis, the residuals ($X_{\text{calculated}} - X_{\text{observed}}$) are analyzed through an autocorrelation plot. This plot is helpful in
determining if there is any cyclic variation remaining in the residuals,
that is, any cyclic variation unexplained by the regression model. The
autocorrelation function is defined as

$$\rho_{xx}(k) = \frac{\gamma_{xx}(t, t+k)}{\sigma_x(t) \sigma_x(t+k)}$$

where $k$ is the number of lags, or time periods separation between the
two observations and $\gamma_{xx}(t, t+k)$ is the autocovariance function,

$$\gamma_{xx}(t, t+k) = E[X(t) - E(X(t)))(X(t+k) - E(X(t+k))]$$

This autocovariance has the same properties as the covariance between
two random variables $X_1$ and $X_2$. If there is no dependence between
values of a series at times $t$ and $t+k$, then $\gamma_{kk}(t, t+k) = 0$. If values
of $X$ at $t$ and $t+k$ tend to have opposite signs, then $\gamma_{xx}(t, t+k)$ will be
negative. If values of $X$ at $t$ and $t+k$ tend to have like signs, then
$\gamma_{xx}(t, t+k)$ will be positive. $\gamma_{xx}(t, t+k)$ depends on the scale of
measurement of $X$. In order to compare time series of different scales
of measurement, it is necessary to define the normalized function of
autocorrelation as above. As with a correlation coefficient, $-1 \leq \rho_{xx}(k) \leq 1$.
In the subroutines used in this thesis, an autocorrelation plot is pre-
pared. A specified number of lags is used as the upper limit for $k$,
the distance between $t$ and $t+k$. In this plot, the resolution, or interval between which changes in autocorrelation may be detected is defined as $\pi/m$ where $m =$ the maximum number of lags. Increasing $m$ yields better resolution, however $m$ should be between .2 and .4 times the total number of observations. In examining the autocorrelation plot, the period of any remaining cyclic variation is determined by calculating the distance between peaks on the plot:

![Diagram showing autocorrelation plot with peaks and period P marked.]

where $P$ is the period. Note that $2\pi/P = \omega$, the frequency, and $\omega$ can also be determined from the abcissa of the spectral density plot to be described. If all cyclic variation has been removed from the residuals, the autocorrelation plot will be reduced to a random grouping of points about the abcissa.

The spectral density plot is generally more valuable than the autocorrelation plot because it is easier to interpret. This plot clearly reveals the relative contribution of each frequency of cyclic variation to the variation of the time series about its mean. This measure of relative contribution is used as a basis for determining the frequencies of the periodic terms to be included in the time series model. The power spectrum of a time series is the Fourier transformation of the autocovariance function:
\[ p(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \gamma(t) \cos \omega t \, dt \]

(Brown 1,397)

With the program used herein, an estimate of the spectral density function is calculated. A "window" is used to calculate a weighted average of the true power spectrum density over the frequencies near the frequency of interest, rather than calculate a single point value. This procedure does introduce some smudging of the powers of close frequencies, that is, makes them difficult to distinguish.

Confidence intervals are necessary in determining from the spectral plot which frequencies make significant contributions to the variations in the time series. The confidence intervals for the programs used here are calculated as follows (Jenkins and Watts 9,255):

**upper control limit**
\[ \bar{s} + \ln \left( \frac{v}{\chi^2_v \left( 1 - \alpha/2 \right)} \right) \]

**lower control limit**
\[ \bar{s} + \ln \left( \frac{v}{\chi^2_v \left( \alpha/2 \right)} \right) \]

where \( v \) = degrees of freedom

\[ v = \frac{2Mb'}{m} \]

\( m = \text{number of lags considered} \)

\( M = \text{number of observations} \)

\( b' = \text{constant for Tukey Hanning window} \)
= 1.33

\( \alpha \) = significance level

\( \bar{s} \) = estimated mean of spectral density plot

\( \chi^2_{\nu}(a/2) \) = Table value of Chi square distribution for the proper degrees of freedom and significance level.

Any frequency with power exceeding the limits should be examined for inclusion in the model. The final model which explains all cyclic variation should have no frequency remaining in the spectral density plot with power exceeding these limits. Another important limit is the bandwidth, or the horizontal limit on the spectral density plot. This limit defines the resolution of frequencies and is defined as

\[ b = b'/m \]

where \( m \) = number of lags

\( b' \) = constant for the window used

(Jenkins and Watts 9,257)

This value should be greater than the plotting resolution, as within the bandwidth one cannot distinguish between frequencies. Spectral analysis is further explained in Granger (6).

2.3.3 Example

As an example of the interpretation of the spectral density plot, the regular sales for station 23, a business district site, is analyzed using harmonic analysis. The plots in Figures 2.1 through 2.4 show the successive reduction in the power of the residual spectral density function. Using the formulae the bandwidth and control limits are calculated:

\[ m = \text{number of lags} = 200 \]

\[ M = \text{number of observations} = 735 \]
\[ b' = \text{window constant} = 1.33 \]

\[ b = \frac{b'}{m} = \frac{1.33}{200} = .00665 \]

degrees of freedom

\[ v = \frac{2Mb'}{m} = \frac{2(735)(1.33)}{200.100} = 7.35(1.33) = 9.76 \sim 10 \]

control limits

\[
\begin{align*}
\chi^2_{10} (.05/2) &= 20.483 \\
\chi^2_{10} (.975) &= 3.247
\end{align*}
\]

\[
\text{From Chi-square table (7,22)}
\]

\[
\begin{align*}
\text{LCL} &= \bar{s} + \ln \left( \frac{10}{20.483} \right) = \bar{s} + \ln(.489) = \bar{s} - .7154 \\
\text{UCL} &= \bar{s} + \ln \left( \frac{10}{3.247} \right) = \bar{s} + \ln (3.08) = \bar{s} + 1.1249
\end{align*}
\]

The mean will vary through the successive plots as the model is expanded. Figure 2.1 illustrates the plot after the removal of a linear trend. The high peak at the beginning of the plot indicates the presence of a long-term cyclic variation, or possibly a quadratic trend. The inclusion of a quadratic trend in the model yields the spectral density function in Figure 2.2. In discussing the data with a company sales analyst, the existence of summer seasonal effects had been suggested, as well as increased weekend sales. There is a broad, flat peak in the raw data which supports the existence of this peak. Such broad, flat peaks are represented by harmonic terms. The spectral plot in Figure 2.2
gives further evidence of the harmonics' importance. The frequencies corresponding to periods of 365 days, 365/2, 365/4, 365/6, 365/8, and 365/12 days are .0172, .0344, .0688, .1032, .1376, and .2064, respectively. Looking at the plot, these first four frequencies all have powers above the control limits. The latter two frequencies have powers which are definite peaks, however they are not in excess of the control limits. Inclusion of these terms yields the spectral plot in Figure 2.3. A significant peak now remains at a frequency of .9050, corresponding to a period of 6.335 days. This is not easily justified by any underlying economic effect. Rather than include such a term which is not a harmonic of the basic period, factors for each day of the week are included in the model, in accordance with the suspected weekend peaks. The resulting plot, Figure 2.4, shows the spectrum reduced in power, with the peaks below the control limits, with the exception of the lower frequency peak, \((\omega = .0650)\). Other harmonics may be included to remove this peak, but one should bear in mind that these lower frequency power estimates are based on smaller sample sizes than higher frequency estimates, and therefore cannot be given the same relative importance. Thus the example discussed has been modeled by what will later be described as a day factor - harmonic model with a quadratic trend.

2.4 Procedure

As a preliminary step to the time series analysis, each data set was plotted and the daily sales stratified by four different classifications for the calculation of means and standard deviations. The classifications are by individual day of the week, weekends versus weekdays,
summer months versus other months, and 1967 versus 1968. This stratification greatly reduces the data, and together with the graphic presentation of the process in the plots gives some clues as to the demand pattern. With the stations being on several different basic levels of volume, it is difficult to make a comparative analysis with respect to the importance of the variations or the similarities among site type groupings. Although no specific conclusions can be drawn, supporting evidence is given to the expected presence of trend, seasonal, and weekly cycle effect. There appears to be a generally increasing trend, an increase in sales during the summer months, and a sales increase over weekends. Indication is given that interstate sites generally are higher than other locations in overall average sales and shopping center sites generally lower. Due to the bulk of the output, only a sample of the results of this program is given in Figure 2.5, for station number 23, regular sales. Table 2.1 presents a summary of the results, with the average sales per day in gallons for both products, at all stations for 1967 and 1968. A wide variation in average sales is evident, as well as the fact that interstate locations are generally stronger.

The calculation of correlation between regular and premium sales gives a rather disappointing lack of correlation (Table 2.2). This indicates the probable requirement of separate models for regular and premium sales. It is worthy of note that the interstate sites generally have higher correlations between regular and premium sales. The overall lack of correlation can be attributed to the possible independence and dissimilarity of the two customer populations for regular and premium
sales, or could indicate that the dominant characteristics of the sales patterns are random fluctuations. Lack of data prevents any investigation of the first hypothesis.

2.3.1 Investigation of Linear-Cyclic Models

The first model types to be explored are the linear-cyclic type models. This involves pure spectral analysis, in which any economically justifiable cyclic term which appears significant is included in the model. For this investigation, station 3, an interstate site with good daily volumes is used. A linear trend is assumed and the detrended residuals yield a spectral density plot with a pronounced peak at approximately 7 days. A lower frequency peak of 326 days is also apparent. The inclusion of the 7 day sine and cosine terms in the model causes a shift in the lower frequency peak to 251 days, and the appearance of a peak at 3.5 days. The 3.5 day peak can be justified on the basis of a harmonic effect, as weekend sales increases would cover both Saturday and Sunday, as evidenced in the stratification. The longer period peak cannot be given any economic interpretation, however. Inclusion of the 3.5 day peak shifts the longer period to 202 days, and it becomes the most significant cyclic component. Further, peaks of significant power appear at 7.3 and 6.79 days. None of these periodic fluctuations can be explained from any known economic basis. Considering the necessity for justification of any non-harmonic terms, sine-cosine pairs for 365 and 182.5 day periodics are included, with the only apparent results being a shift of the period of the long term variation to 73 days. This corresponds to 365/5, a harmonic term. Proceeding in this manner, several
more periods become significant, all of which are relatively near harmonic periods. It is felt that the smudging effect of using windows to obtain spectral density averages gives these results, and the harmonic terms are included. The addition of the harmonic $365/3$ yields a spectral plot with a peak at $6.78$ days, in addition to peaks near harmonics. This is not an expected periodic variation, however it may be explained on the basis of the average length of time between purchases by the customer population. The length of time between gasoline purchases may not be tied to phenomena such as pay periods, with the availability of credit cards, but rather to the gasoline consumption, the mileage driven on the average by the customers. Inclusion of the pair of terms for this period does not significantly improve the results of the model, however, and peaks are now present on either side of the frequency representing this period, the frequencies corresponding to $7.38$ and $6.826$ days. Peaks are also significant at $96.61$ and $50.24$ days, these peaks being close to the harmonics $365/4$ or $91.25$ days, and $365/8$, or $45.625$ days. The investigation of linear-cyclic models appears fruitless at this point. The presence of periods of non-integral numbers of days is puzzling when they are not harmonics, particularly the periods of roughly one week in length. A new approach is desired which will offer a better explanation of this phenomena.

2.4.2 Harmonic - Day Factor Models

In addition to changing the direction of the investigation of model types, it is evident at this point that the procedure is not adequate. The regression program used in the analysis has been a simple multiple
linear regression program. Simply adding new terms to the model nearly always increases the $R^2$ value and lowers the standard error of estimate, although some of the terms may make minor contributions to the predictive ability of the model. Further, interactions between the terms added to the model and those already in the model cannot be examined. The solution to these problems is the adaptation of a stepwise regression procedure for use with the spectral analysis routines. The stepwise regression routine written by IBM and modified by the KSU computing center staff is further modified and used with the same spectral analysis routines as used with simple linear regression. The resulting program appears in Appendix A. Many advantages are realized with this modified procedure. The program provides printouts at each step of the procedure, with statistics pertaining to the regression at each step. The significance of each variable in the regression is guaranteed to meet or exceed preselected levels. These levels are specified for entry and deletion of variables, and at each step in the regression, partial F tests are performed to determine if any variable should be deleted and which, if any, new variable should be added to the model.

A new approach is desired which will remedy the shortcomings of the models previously fitted to the data. While it is evident from the stratification analysis that there are differences in average daily sales for all days, the weekend-weekday differences being generally greater, little can be concluded about the significance of these differences. If there are differences among all the days' average sales, this cannot be expressed in a linear-cyclic model. The sine
and cosine terms for the 7 day period can be used to express only one 7 day periodic fluctuation. Harmonics serve only to flatten the peak over two or more days, to include, for example Saturday and Sunday in a weekend peak in sales. If, however, there are significantly lower sales on Wednesdays, this effect cannot be modeled with any other cyclic term. Thus a model is proposed which includes a dummy variable for 6 of the days of the week. The addition of 7 variables would introduce a redundancy, as the base level of the model represents one day. A matrix of dummy variables is generated in the transformation subroutine of the stepwise program:

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<th>X_3</th>
<th>X_4</th>
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</table>

This model is termed a day factor model. The linear trend term is included along with the annual seasonal terms for the sine and cosine of 365 and 182.5 day periods.

Another possibility is that station number 3 is not truly representative of all stations, or even of its site type. Further, there are three other site types to be investigated. A random sample of each site type is established in an attempt to examine the differences,
if any, between the demand patterns of the various site types, and the similarities among stations within a given site type classification. The resulting sample includes stations 1 and 11 from the residential sites, stations 4 and 15 from the shopping center sites, stations 3, 6, and 21 from the interstate sites, and stations 10 and 23 from the business sites. Each of the sets of data for each site type are for regular gasoline sales. There are varied results in the stepwise regressions, as exhibited in Tables 2.3 through 2.6.

Looking first at Table 2.3, the results for the interstate sites, the stepwise regression has accepted all of the available terms for all of the models. These stations are operating on different base levels, however they have linear trend terms indicating comparable rates of growth. The sine and cosine pairs for both harmonic terms are of comparable magnitudes, as are the day factor terms. The \( R \) values are also comparable, as are the standard errors of estimate. These stations all appear to have similar demand patterns. The business sites, in Table 2.4, do not yield as good results, their \( R \) values being significantly below those of the interstate sites. The two results are also dissimilar with respect to the significant day factor terms. With Sunday as a base level, station 10 appears to have significant differences between all of the days of the week, where station 23 has lower sales on Tuesday, Wednesday, and to a lesser degree, on Friday. The same harmonics are significant in both stations, with the sine of \( 2\pi t/182.5 \) being excluded from both models. This would indicate a different seasonal effect in these two sites from the seasonal effect in the interstate sites. The linear trend terms for both sites are comparable in
effect, although station 23 experiences a larger growth rate. Proceeding to the residential sites, Table 2.5, a similarity is seen between these sites and the business sites in the important seasonal harmonics. The sine 2πt/182.5 is not a significant term in either of these models. The day factors of the two models for residential stations are comparable. It is interesting that the significant day factors in these two station models are the same as those in station 23, a business site. The exact classification of stations according to site types could allow for a station to have characteristics of several groups, or to be designated improperly if it is difficult to assess the nature of the site. The resulting R for both of these stations is quite low, however, lower than any model examined so far. Finally, turning to Table 2.6, the shopping center sites, more difference is found between the models for these two stations than any others within the same site type classification. Station 4 has a high R of .87, which exceeds any R previously attained. The terms are all accepted as significant, just as with the interstate site models. In contrast, station 15 has a model in which only one day factor term has been included. This station has no differences in daily sales, except for a decrease on Mondays. The station has a very poor overall sales volume, and a weak growth. The results for this station should not be weighed heavily, as it appears to be operating under abnormal conditions. It could be a new location.

Although the overall explanatory power of these models is not impressive, there is an encouraging similarity among the models within the same site type classification. It may be possible to represent the stations within a given site type by one general model. There does
not appear to be strong evidence supporting the use of less than four models for the representation of regular gasoline sales, and the models should all be improved.

For each of the site types except the interstate sites, there is evidence of a very long periodic fluctuation, or possibly a quadratic growth term in the spectral density functions. This is indicated by the first points of the spectra being at the maximum values. Caution is required in the interpretation of these results, as there are several dangers in inserting a quadratic term in the model. Foremost is the possibility that the actual processes do not possess quadratic terms at all, but some long term cyclic variations. There is not enough data to investigate this possibility, however.

Secondly, the use of a higher degree growth term in the model greatly limits its period of usefulness as a forecasting model without the use of adaptive fitting to moderate the coefficient of the quadratic term as its effect diminishes. This term is included, realizing these pitfalls, as the simulation is limited to two years or less. The purpose of the models is, after all, to model the existing data, not produce forecasts, and if this term improves the quality of the models, it will improve the accuracy of the simulation over this time span. A physical interpretation of this term would be subject to error without a longer time series to justify the interpretation. It is apparent, however, that the actual existence of a quadratic term is doubtful, as this rate of growth could not extend indefinitely in time. More likely would be that this data is from an increasing section of a logistic
curve, or again, some segment of a longer term cyclic variation.

In inserting this term into the model, it is necessary to use a scaling factor. The actual term used is \( t^2/10000 \). This prevents any danger of loss of numerical accuracy in the regression. The \( t^2 \) term would become quite large toward the latter range of the time series, and in comparison with the magnitudes of the other terms. More harmonics of the annual seasonal term are included; from indications of the spectral density plots, this is known to be a very broad, flat peak, extending over several months. In an attempt to express this seasonal variation more accurately, the sine and cosine terms for 91.25, 60.83, 45.625, and 30.416 day periods, all harmonics of 365 days are included in the proposed model. Another sample is selected for these experiments including the stations listed below:

<table>
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<tr>
<th>Site Type</th>
<th>Regular</th>
<th>Premium</th>
</tr>
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<tbody>
<tr>
<td>Interstate Sites</td>
<td>3, 5, 7</td>
<td>3, 6</td>
</tr>
<tr>
<td>Business district sites</td>
<td>8, 13, 22, 24</td>
<td>10, 8, 23</td>
</tr>
<tr>
<td>Residential District Sites</td>
<td>12, 14, 16, 20</td>
<td>1, 2, 19</td>
</tr>
<tr>
<td>Shopping Center Sites</td>
<td>9, 17, 18</td>
<td>9, 17, 25</td>
</tr>
</tbody>
</table>

Within the sample sets, the results are fairly consistent. There are some variations in the day factors which are selected, but the seasonals and their levels are fairly consistent. A thorough examination of the results leads to the conclusion that a good representation of the demand patterns can be obtained with the use of 8 models, one for regular and one for premium sales under each of the four site types. The results for interstate sites, regular sales are given in Table 2.7.
These models have the highest R values of all models developed. Note that the same terms appear significant in both station models. In Table 2.8, the business sites, the results of the models are seen to be similar within the classification. The linear and quadratic components are both positive in the interstate models, however the linear terms in these models are all negative, with positive quadratic components in the models of stations 8, 13, 22, and 24. This would dampen out the effect of the quadratic growth component. The same harmonics, for the most part, are important in all of the models for business sites. There is included a cosine term for a period of 60.83 days and sine for a period of 91.25 days in the models for stations 13, 22, 24, which are not present in the model for station 8. The day factor terms included in the models are noted to be generally the same, the only exception being the inclusion of a Saturday term for station 22. The results of the residential site models are given in Table 2.9. These results are not as good as either the business or interstate sites, and there appears to be less similarity among these stations than those with the other two groups. The linear growth components in these models are again negative in sign, dampening the effect of the quadratic growth terms. The higher frequency harmonics chosen for inclusion in these models vary widely from station to station, with little consistency among the day factors, except for Tuesday and Wednesday sales being lower days than the others in all cases. Shopping centers, Table 2.10, again are among the most poorly fitted models, with their R values being as low as the residential sites. In their case, however, the linear
trends have positive coefficients while the quadratic trend terms are negative. These stations thus exhibit very poor growth rates, in addition to being among the lowest volume sites. The harmonic terms included in the models are generally consistent, however only the longer period terms are included. Station 9 includes all of the day factor terms, while stations 17 and 18 only include two. Indications at this point are that the shopping center and residential demand patterns are not easily modeled by time series techniques. There may be other underlying factors in determining these demand patterns than those affecting the interstate and business district sales. Activity at a shopping center site may be based more on the activity in the center itself, and residential patterns may be determined by similar considerations, such as housewives' shopping habits. Further, these two site types seem to be less affected by weekend and summer seasonal activities.

In examining the premium sales results, Table 2.11 shows for interstate sites less impressive results than the regular models. This indicates that premium sales are affected with regard to seasonal variation differently than regular, as fewer harmonic terms are included. The growth is predominantly reflected in the quadratic growth term. Daily differences in sales levels are seen to still be significant. Table 2.12 shows the results for the premium sales at the business sites. The results are not as dissimilar to the interstate results as they are with regular sales. The trend appears to be predominately quadratic, and the seasonal harmonics selected are comparable to the ones present in the interstate model. Residential premium sales, in Table 2.13, are dissimilar in demand pattern compared with the other two site types.
Again, as with regular, there appears to be more unaccounted variation in these demand patterns. Stations 1 and 2 have more common terms than station 19 although their models' R values indicate that the models are not sufficient. Shopping center sites, in Table 2.14, show no similarities to the other groups. The lack of a quadratic growth term and a weak linear growth term are the primary differences between these models and those under other classifications. Stations 9 and 25 show similarities in their model terms, however station 27 appears to have a different demand process with regard to daily patterns.

Within the sample sets, the results are fairly consistent, although not adequate in their explanation of the demand fluctuation to enable use of the models in forecasting. A large amount of variation remains which appears random, but is more likely tied to processes not related to time series. It is felt that the models, if they were generalized, could be used in the simulation however, as actual forecasting is not to be done. The problem, then, is to obtain general coefficients for use in modeling each station under a given classification. There is difficulty in obtaining these general coefficients, even though the standard deviation of each coefficient is given for each sample model. There is no statistically valid way to get an overall average and standard deviation from this information.

2.4.3 Combined Models

Rather than use some judgement criteria, all of the data under each site type classification and each gasoline grade is run through the stepwise regression routine with the critical values for entering and
deleting variables set at zero. This allows the acceptance of every term into the model, in the order of their significance to the model. A second set of dummy variables is generated, one for each of the stations in a given site type classification, less one, as one station is represented by the base level of the model. The final results are presented in Tables 2.15 through 2.18. There are graphs of the changes in R values and standard errors of estimates presented in Figures 2.6-2.13. These graphs are used in determining the final models.

In determining the cut off points for the models, a "backward elimination" procedure is followed, with all variables eliminated beyond the point of a .005 increase in the standard error of estimate. The final models appear in Tables 2.19 through 2.26. The R values are deceivingly high for these runs, the reason being that the differences in the base levels of the different stations within a group account for the larger part of the total deviation of the values of the time series about their means. Thus the seasonal, day, and remaining unexplained effects are overshadowed. On an individual station basis, the predictive power of the models is low. For the purposes of demand modeling, however, it was felt that these models would be adequate. The problems would enter only if an attempt were made to extend the use of these models to forecasts.

2.5 Concluding Comments on Demand Modeling

The above analysis of the demand patterns is costly and time consuming, without producing spectacular results. The external factors such as would have been included in correlational models may produce
more accurate results, but they too would have to be expressed as a
time series, or some recursive formulae developed to produce their
values for determination of the corresponding sales volumes. The final
spectral plots exhibit no remaining strong periodic fluctuations which
can be reasonably explained on an economic basis, thus the unexplained
deviations of the time series appear "random" from a time series point
of view. The models do meet the primary goal of simplicity and are
felt as being accurate enough to use in the simulation.

2.6 Use of the Models

Within the simulation, a "forecast" and "actual" process are to
be used. It is not practical to use the derived models with adaptive
fitting, as they would be if used for forecasting. If any form of
adaptive fitting is used it would be necessary to store the actual
series during the simulation in order to get an actual demand for the
forecast to track. Again this is a large amount of data to be stored
and referenced which would greatly slow the simulation. Further, there
would be a time lag in the response of an adaptive fitting technique to
changes in the demand pattern. With time series of two years in length,
all of the data would be required to get the initial estimates for the
parameters, with an annual cycle, leaving no new data to use in applying
the adaptive process.

With the previously mentioned difficulties in mind, the simplest
approach is to use the standard errors of estimate from the eight models
as a random error term which, when added to the value obtained from a
model at a given time, would represent the "actual" process. These errors
are to be generated from a normal distribution with mean zero and a standard deviation equal to standard error of estimate for the model. Thus an idealized "forecast" is used, with errors having mean zero.
## DAILY AVERAGE SALES

(IN GALLONS)

<table>
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<td>MEAN STD. DEV.</td>
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*R - RESIDENTIAL SITE  
I - INTERSTATE SITE  
S - SHOPPING CENTER SITE  
B - BUSINESS DISTRICT SITE

TABLE 2.1
### CORRELATION BETWEEN REGULAR AND PREMIUM GASOLINE SALES

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**TABLE 2.2**
RESULTS WITH DAY FACTOR - HARMONIC MODEL WITH LINEAR TREND

REGULAR GASOLINE SALES

INTERSTATE SITES

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TABLE 2.3
RESULTS WITH DAY - FACTOR HARMONIC MODEL

REGULAR GASOLINE SALES

BUSINESS SITES

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**Table 2.5**

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RESULTS WITH DAY FACTOR - HARMONIC MODEL

REGULAR GASOLINE SALES

SHOPPING CENTER SITES

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TABLE 2.6
RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TRENDS

REGULAR GASOLINE SALES

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**TABLE 2.8**
### RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

#### REGULAR GASOLINE SALES

#### RESIDENTIAL SITES

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**Table 2.9**
RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TEND

REGULAR GASOLINE SALES

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Table 2.9 (Cont.)
## RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TEND

### REGULAR GASOLINE SALES

#### SHOPPING CENTER SITES

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**TABLE 2.10**
RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

PREMIUM GASOLINE SALES

INTERSTATE SITES

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TABLE 2.11
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**Table 2.1**
### RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

#### PREMIUM GASOLINE SALES

##### RESIDENTIAL SITES

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**TABLE 2.13**
RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

PREMIUM GASOLINE SALES

SHOPPING CENTER SITES

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TABLE 2.14
## RESULTS WITH COMBINED MODEL

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**TABLE 2.15**
### RESULTS WITH COMBINED MODEL

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**Table 2.16**
## RESULTS WITH COMBINED MODEL

### RESIDENTIAL SITES

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### TABLE 2.17
RESULTS WITH COMBINED MODEL

SHOPPING CENTER SITES

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<td>0.9486</td>
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TABLE 2.18

STATION 4 BASE LEVEL
FINAL MODEL INTERSTATE SITES

REGULAR GASOLINE SALES

R = 0.9435
S.E.E. = 84.8889
CONSTANT = 1039.0321

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STATION 3 BASE LEVEL

TABLE 2.19
FINAL MODEL INTERSTATE SITES
PREMIUM GASOLINE SALES

R = 0.9064
S.E.E. = 69.5207
CONSTANT = 700.3403

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STATION 3 BASE LEVEL

TABLE 2.20
FINAL MODEL BUSINESS SITES

REGULAR GASOLINE SALES

\[ R = 0.9444 \]

\[ S.E.E. = 66.4963 \]

\[ \text{CONSTANT} = 638.3573 \]

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STATION 8 BASE LEVEL

TABLE 2.21
FINAL MODEL BUSINESS SITES

PREMIUM GASOLINE SALES

$R = 0.9355$

S.E.E. $= 55.2687$

CONSTANT $= 404.9542$

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STATION 8 BASE LEVEL

TABLE 2.22
FINAL MODEL RESIDENTIAL SITES

REGULAR GASOLINE SALES

\[ R = 0.9593 \]
\[ S.E.E. = 65.0018 \]
\[ \text{CONSTANT} = 820.2547 \]

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</tr>
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<td>STATION 19</td>
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STATION 1 BASE LEVEL

TABLE 2.23
FINAL MODEL RESIDENTIAL SITES

PREMIUM GASOLINE SALES

R = 0.9469
S.E.E. = 48.3272
CONSTANT = 525.0679

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</tr>
<tr>
<td>STATION 2</td>
<td>-210.2544</td>
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<td>STATION 11</td>
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</tr>
<tr>
<td>STATION 12</td>
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</tr>
<tr>
<td>STATION 14</td>
<td>-41.4327</td>
</tr>
<tr>
<td>STATION 16</td>
<td>-268.2694</td>
</tr>
<tr>
<td>STATION 19</td>
<td>-63.0939</td>
</tr>
<tr>
<td>STATION 20</td>
<td>-75.0231</td>
</tr>
</tbody>
</table>

STATION 1 BASE LEVEL

TABLE 2.24
FINAL MODEL SHOPPING CENTER SITES
REGULAR GASOLINE SALES

\[ r = 0.8918 \]

\[ \text{S.E.E.} = 44.4480 \]

\[ \text{CONSTANT} = 280.3977 \]

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINEAR TREND</td>
<td>0.3259</td>
</tr>
<tr>
<td>QUADRATIC TERM ( (t^2/10000) )</td>
<td>-2.4364</td>
</tr>
<tr>
<td>SINE ( 2\pi t/365 )</td>
<td>-15.3731</td>
</tr>
<tr>
<td>COSINE ( 2\pi t/365 )</td>
<td>-9.3452</td>
</tr>
<tr>
<td>SINE ( 2\pi t/182.5 )</td>
<td>8.1361</td>
</tr>
<tr>
<td>COSINE ( 2\pi t/182.5 )</td>
<td>10.3640</td>
</tr>
<tr>
<td>COSINE ( 2\pi t/91.25 )</td>
<td>5.6580</td>
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<tr>
<td>MONDAY</td>
<td>-44.5386</td>
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<tr>
<td>TUESDAY</td>
<td>-24.7832</td>
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<tr>
<td>WEDNESDAY</td>
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<tr>
<td>FRIDAY</td>
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<td>STATION 9</td>
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<td>STATION 15</td>
<td>-213.2340</td>
</tr>
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<td>STATION 17</td>
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<tr>
<td>STATION 18</td>
<td>-15.8844</td>
</tr>
<tr>
<td>STATION 25</td>
<td>-17.3497</td>
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</tbody>
</table>

STATION 4 BASE LEVEL

TABLE 2.25
FINAL MODEL SHOPPING CENTER SITES
PREMIUM GASOLINE SALES

R = 0.8749
S.E.E. = 34.1023
CONSTANT = 239.7498

<table>
<thead>
<tr>
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<td>SINE 2πt/182.5</td>
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<tr>
<td>COSINE 2πt/182.5</td>
<td>6.7138</td>
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<td>COSINE 2πt/30.416</td>
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<td>MONDAY</td>
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<td>TUESDAY</td>
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<td>WEDNESDAY</td>
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<td>SATURDAY</td>
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<td>STATION 9</td>
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<td>STATION 25</td>
<td>-47.0980</td>
</tr>
</tbody>
</table>

STATION 4 BASE LEVEL

TABLE 2.26
UCL = -0.708
\( \hat{S} = -1.8320 \)

FIGURE 2.2
UCL = -0.5971
\bar{S} = -1.7220

FIGURE 2.4
## Analysis of Data by Stratification

### Regular Grade Gasoline - Station 23

#### Day to Day

<table>
<thead>
<tr>
<th></th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
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<tbody>
<tr>
<td>Mean</td>
<td>1017.61</td>
<td>969.44</td>
<td>971.93</td>
<td>1020.39</td>
<td>995.43</td>
<td>1032.15</td>
<td>1046.15</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>148.43</td>
<td>128.29</td>
<td>134.60</td>
<td>125.85</td>
<td>136.40</td>
<td>122.54</td>
<td>122.66</td>
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</tbody>
</table>

#### Weekends - Weekdays

<table>
<thead>
<tr>
<th></th>
<th>Weekends</th>
<th>Weekdays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1033.13</td>
<td>997.44</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>121.94</td>
<td>136.77</td>
</tr>
</tbody>
</table>

#### Winter, Fall, Spring - Summer

<table>
<thead>
<tr>
<th></th>
<th>Other</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>136.82</td>
<td>1064.38</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>136.64</td>
<td>118.11</td>
</tr>
</tbody>
</table>

#### 1967 - 1968

<table>
<thead>
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<th>1967</th>
<th>1968</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>446.76</td>
<td>1064.38</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>169.15</td>
<td>131.76</td>
</tr>
</tbody>
</table>

**Figure 2.5**
INTERSTATE PREMIUM MODEL

R VS. VARIABLES

SEE VS. VARIABLES

NUMBER OF VARIABLES

FIGURE 2.7
SHOPPING CENTER PREMIUM MODEL

R VS VARIABLES

SEE VS VARIABLES

NUMBER OF VARIABLES

FIGURE 2.13
CHAPTER III

SYSTEM SIMULATION

It is necessary to make certain assumptions pertaining to operating policies for the distribution system where information is lacking, as well as for purposes of simplification. Although some of the assumptions place limitations on the accuracy and applicability of the simulation, special emphasis is placed on keeping the hypothetical system as realistic as possible. In this chapter, the distribution system as hypothesized is discussed, with assumptions justified and the resulting limitations of the assumptions pointed out.

3.1 Simplified Inventory Considerations

There are factors contributing to the complexity of the inventory control problem in this case which cannot be ignored, but prevent analytical solution of the problem. Rather than oversimplify the problem, a simulation approach is taken in which critical indicators of the inventory system are monitored and their comparative values used as a basis for evaluating alternative operating procedures.

3.1.1 Operating Assumptions

The simulated system operates under the assumption that the sales to the individual stations are on a consignment basis. The advantage of consignment sales is that this policy allows the company to control deliveries. In gaining this control, the company assumes all costs associated with carrying inventory. The proposed system of order
dispatching operates from a set of daily demand forecasts. The advantage of using forecasts is primarily in more efficient transportation planning being possible with advanced clues to a given day's slate of orders. As no forecasting system is perfect, there is a probabilistic nature to the anticipated demand. There is a possibility that the actual station inventory will reach the reorder level before an order is delivered based on the forecast level. In the simulated system, this actuates an expedited order, which is a priority order requiring delivery on a single station route. As there may in actuality be extra costs for expediting orders, and these costs are unknown, the number of expedited orders to each station is tabulated. In making the restriction that these orders must be served on single station routes, it is recognized that these orders would probably be placed after any delivery planning were done and the vehicles dispatched.

In dispatching a forecast based order, there is danger that the actual station requirement may differ from the order quantity. The forecasts are updated to the actual status only upon delivery of an order. The costs of sending an order quantity in excess or less than actual requirements are unknown. Therefore, in the case of an order quantity in excess of actual requirements, the amount of excess is tabulated and reported in the simulation. An order size less than the requirements results in a quicker reorder situation.

The demand information given is on the basis of daily demands. The distribution of these demands over the day is unknown, presenting difficulties in the consideration of stockouts. If the predicted daily demand at a given station is such that the station's inventory will be
depleted to zero at some time during the day, it is unknown exactly when
during the day this will happen. If an order is delivered that day, a
stockout may be prevented if it is delivered quickly enough. With in-
sufficient information to accurately model this occurrence, the assumption
is made that the order will arrive at the end of the day; all of the sales
beyond those covered by inventory are lost. These lost sales are tabu-
lated, by regular and by premium, for the entire system. Although total
gallons lost sales is assumed as the worst possible in terms of gallons,
it is still not a true picture of what happens in the real situation.
The reorder point of 25% of tank capacity is set to avoid pumping the
sludge and water from the tanks. There is more likely an absolute min-
imum level beyond which a dealer will not pump to avoid pumping these
impurities into his customers' automobiles. The assumed point of zero
inventory is thus a simplification, and the total lost sales may be
higher in actual conditions.

There is an element of interdependence among the stations, with
relation to transportation costs. These costs are part of the cost of
order placement, depending on the delivery scheme. In cases where a
station receives an order directly from the terminal, where the vehicle
has only one stop on its route, the transportation cost can be calculated
for the individual station. In the case of multistop routes, it is dif-
ficult to assign the costs of delivery to each individual station. The
overall cost or overall average cost per gallon delivered is more
readily calculated for the entire system. These are the costs considered
in the simulation.
Looking more closely at the transportation cost, it is apparent that the cost of transit is only part of this cost. Constant times involved in vehicle loading and unloading plus the variable times associated with pumping rates, which vary with order size, induce costs, as personnel and equipment are tied up. These times and rates are used in the simulation, however there are also systemic costs incurred in the placement of an order and subsequent delivery. These costs result from billing, vehicle dispatching, and monitoring and updating any existing inventory/forecasting system. These costs are difficult to assess, and as an alternative, the number of trips made by the fleet and the number of deliveries to each station are monitored in the simulation.

The average level of inventory at each location is reported and carrying costs calculated on the basis of the given percentage of product cost, 13%. Volume loss due to theft, leakage, and evaporation from storage tanks is considered as negligible.

3.1.2 Summary of Indicators

The following indicators of system performance are reported on a specified regular basis during the simulation, compiled over the report period:

1. Average number of orders.
2. Number of trips with excess loads.
3. Total gallons of excess load.
4. Average transportation cost per gallon delivered.
5. Total number of deliveries to each station.
6. Average daily demand for both products at each station.
7. Average order size for both products at each station.
8. Average inventory level for both products at each station.
9. Station inventory carrying cost.
10. Gallons of lost sales, for each product, accumulated for all stations.
11. Average total system cost per gallon sold.

3.1.3 Station Data Management

The stations compose one of the major entity groups of this simulation, and information regarding these entities is referenced and manipulated throughout the simulation. In keeping track of this information, a matrix arrangement is used to store all collected statistics and input parameters. The simulation program appears in Appendix A, with a brief description. Throughout the discussion, reference will be made to various statistics and parameters. To facilitate this discussion, they are defined:

SMRM - Station master reference matrix.

- **SMRM(J,1)** - Station identification number.
- **SMRM(J,2)** - Station regular gasoline storage tank capacity.
- **SMRM(J,3)** - Station premium gasoline storage tank capacity.
- **SMRM(J,4)** - Station regular gasoline reorder level.
- **SMRM(J,5)** - Station premium gasoline reorder level.
- **SMRM(J,6)** - Forecast current inventory status for regular gasoline.
- **SMRM(J,7)** - Forecast current inventory status for premium gasoline.
SMRM(J,8)  - Actual current inventory status for regular gasoline.

SMRM(J,9)  - Actual current inventory status for premium gasoline.

SMRM(J,10) - Cumulative daily inventory levels for regular gasoline.

SMRM(J,11) - Cumulative daily inventory levels for premium gasoline.

SMRM(J,12) - In the program for compartmentalized vehicles, total number of expedited orders to station J.

In the program for non-compartmentalized vehicles, number of expedited orders for regular gasoline.

SMRM(J,13) - In the compartmentalized vehicles program, date of the last delivery to station J.

In the non-compartmentalized vehicles program, number of expedited orders for premium gasoline.

SMRM(J,14) - Total number of deliveries in the compartmentalized vehicles program.

Number of regular deliveries in the non-compartmentalized vehicles program.

SMRM(J,15) - Cumulative order sizes for regular orders.

SMRM(J,16) - Cumulative order sizes for premium orders.

SMRM(J,17) - Cumulative daily demand for regular gasoline.

SMRM(J,18) - Cumulative daily demand for premium gasoline.

SMRM(J,19) - Unused in the compartmentalized vehicles program.

Total number of premium orders in the non-compartmentalized vehicles program.
There are two files associated with the stations which are used in determining the daily delivery schedule. OFILE is a file of the order quantities for stations requiring delivery. It is a $2 \times 25$ array, the columns denoting individual stations, and the two rows denoting the regular and premium order quantities. NPR is a file of station priority codes. In the compartmentalized vehicles program, it is a vector, consisting of 25 cells, one for each station. In each station's cell is a code number; 0 for no order in the current day, 1 for a normal order, and 2 for a priority order. Further, if an order is deferred in a current day, the priority code 4 indicates this occurrence in the next day. This priority file is a $2 \times 25$ array in the non-compartmentalized vehicles program. Again there are columns for each station, and a row for each product type. The information is coded in like manner to the compartmentalized vehicles case.

3.2 Demand Generation

Within the simulation, two processes describing demand for both products at each service station are in effect at all times, a forecast and an actual process. Both of these processes are generated from the set of demand models established in Chapter 2. Each day, the forecast demand for each of the eight model types is calculated:

$$F_m(t) = \text{Trend} + \text{Seasonal} + \text{Day Factor}$$

Where the above three components of the models are functions of the current simulated time. For a given station $i$, the proper model types for regular and premium grade gasoline sales are known. The model base forecasts are modified for a given station by the addition of the
station level factor:

\[ DRF = F_m(t) + S_{Ir} \]
\[ DPF = F_m(t) + S_{Ip} \]

Where \( DRF = \) the regular forecast for station I.
\( F_m(t) = \) the base forecast for the appropriate model.
\( S_{Ir} = \) station level adjustment for station I, regular gasoline.
\( DPF = \) premium forecast for station I.
\( S_{Ip} = \) station level adjustment for station I, premium gasoline.

Note that for the stations which were represented by the base level of the models, that is, not represented by dummy variables, the adjustment factors will be zero. The actual demand at a station I is then determined by the addition of a normally distributed random variation to the forecast.

\[ DRA = DRF + \varepsilon \]
\[ DPA = DPF + \varepsilon \]

Where \( \varepsilon \sim \text{NID}(0,\sigma^2) \)

\( \sigma = \) the standard error of estimate of the appropriate model.

\( DRA = \) actual station demand for regular gasoline.
\( DPA = \) actual station demand for premium gasoline.

The random normal variation is generated by use of a modified random number generator from the IBM Scientific Subroutine Package (8). This generator yields uniformly distributed random numbers from the
interval (0,1). In conversion to a normally distributed random number, the formula from Burr (2) is used:

\[ z = \frac{(1-N)^{-0.16239} - 1.20517 - (N^{-0.16239} - 1.)20517}{.3240} \]

Where \( N \) = a uniformly distributed random number in the interval (0,1), and \( z \) is a random number from the standard normal distribution.

This method of generating a normal deviate has been tested by use of a Chi-square test before use and proved to adequately produce the desired results.

Each model has a standard error of estimate which is used as the standard deviation of the forecast error. The standard normal deviate is thus converted to the proper normal distribution by the formula:

\[ z' = z \sigma \]

Where \( z \) = the standard normal deviate.

\( \sigma \) = the standard error of estimate for the appropriate model.

The implication of obtaining an actual and forecast demand by this method is that the forecast is idealized, i.e., has a mean error value of zero, the mean error being normally distributed.

With this method of generation of forecasts and actual demands, there is no guarantee that negative forecast and actual demands will not be generated, particularly at low sales stations. This occurrence in the simulation will result in the substitution of a zero value for the generated demand.
3.3 Order Actuation

The actual and forecast demands at the individual stations are generated on a daily basis and the current actual and forecast station inventory levels updated:

\[
\begin{align*}
SMRM(J,6) &= SMRM(J,6) - DRF \\
SMRM(J,7) &= SMRM(J,7) - DPF \\
SMRM(J,8) &= SMRM(J,8) - DRA \\
SMRM(J,9) &= SMRM(J,9) - DPA
\end{align*}
\]

The simulated order scheduling and dispatching systems operate on the basis of the forecasts, except in the case of expedited orders. Only upon order delivery is the forecast inventory status corrected to the actual status.

The criteria of 25% of storage tank capacity is used as the reorder level in this simulation. An order is actuated when the forecast or actual inventory status reaches this level. If the forecast status reaches this level first, a normal order procedure is followed; order actuation by the actual level creates a priority order. In scheduling normal orders, the lack of the demand distribution over a day presents the need for simplification. With a simulated time increment of one day, it is unknown when a delivery will be made during the day. Likewise, it is unknown what the exact inventory level will be. All that is known is that total daily demand will deplete the inventory level to the reorder point. Thus in determining the order quantity based on forecast status, the amount shipped is based on the difference between the previous day's inventory level and the tank capacity. This restricts the order quantity to a smaller amount,
although not necessarily less than the actual requirement, as the forecast levels contain accumulated errors.

In the case of expedited orders, these are considered as being actuated by the station manager calling in to the terminal. The difference between the actual level and tank capacity is shipped, the exact requirement.

3.3.1 Summary of Order Actuation

1. **Actuation by forecast inventory levels.**

   If the forecast demand for the current day will deplete a station's inventory level below the reorder point for either product, an order is actuated:

   \[ \text{SMRM}(J,6) \leq \text{SMRM}(J,4) \]

   Where \( \text{SMRM}(J,6) \) = forecast inventory level at the end of the day, for station \( J \).

   \( \text{SMRM}(J,4) \) = reorder point, regular gasoline, for station \( J \).

   The order quantity is determined:

   \[ \text{OFILE}(1,J) = \text{SMRM}(J,2) - (\text{SMRM}(J,6) - \text{DRF}) \]

   Where \( \text{OFILE}(1,J) \) = order quantity, regular gasoline, station \( J \).

   \( \text{SMRM}(J,2) \) = regular storage tank capacity, station \( J \).

   \( \text{DRF} \) = forecast demand for the current day, station \( J \).

   The proper cell in NPR is set to 1.
Likewise for premium gasoline an order is actuated if:

$$\text{SMRM}(J,7) \leq \text{SMRM}(J,5)$$

Where  $$\text{SMRM}(J,7)$$  = forecast inventory level for premium gasoline at station J.

$$\text{SMRM}(J,5)$$  = reorder point for premium gasoline, station J.

The order quantity being:

$$\text{OFILE}(2,J) = \text{SMRM}(J,3) - (\text{SMRM}(J,7) - \text{DPF})$$

Where  $$\text{OFILE}(2,J)$$  = order quantity, premium gasoline, station J.

$$\text{SMRM}(J,3)$$  = premium storage tank capacity, station J.

$$\text{DPF}$$  = forecast demand for premium gasoline, at station J, for the current day.

The proper cell in NPR is set to 1.

2. Actuation by actual inventory levels.

An order is actuated when the actual level of inventory in the current day becomes less than the reorder point, and an order has not been actuated by the forecast level:

$$\text{SMRM}(J,8) \leq \text{SMRM}(J,4)$$

Where  $$\text{SMRM}(J,8)$$  = actual inventory level of regular gasoline at station J.

The order quantity is determined:

$$\text{OFILE}(1,J) = \text{SMRM}(J,2) - \text{SMRM}(J,8),$$

and the proper cell in NPR, the priority indicator, is set to 2.
Likewise, for premium gasoline and order is actuated if:

\[ SMRM(J,9) \leq SMRM(J,5) \]

Where \( SMRM(J,9) \) = actual premium inventory level at station J.

The reorder quantity is determined:

\[ OFILE(2,J) = SMRM(J,3) - SMRM(J,9), \]

and the proper priority indicator in NPR is set to 2.

In the case of compartmentalized vehicles, if either grade of gasoline actuates an order, both will be delivered, in amounts corresponding to the above formulae. In the case of the non-compartmentalized vehicles, the orders are scheduled independently.

3.4 Weekend Planning Horizon

The terminal is assumed to operate only six days a week in this simulated system. For this reason, in scheduling Saturday shipments, Sunday demands must be considered. On Saturdays, demands for both days are generated. If no order is scheduled from Saturday's updated status for a given station, the projected Sunday status is examined. If the forecast of the Sunday inventory level actuates an order, the order quantity is the difference between Saturday's inventory level and the tank capacity. Priority orders are also possible, their quantity being the actual requirement.

3.5 Order Delivery

The parameters of the simulation to be investigated are those describing fleet operation, thus most directly affecting order delivery.
The close interaction of the inventory system with the order delivery system will be evident as these parameters are varied. There are two major modes of operation considered, the compartmentalized vehicles and the non-compartmentalized vehicles. Within these two modes of operation all vehicles are assumed identical. It is assumed that vehicle operating costs are independent of the mode of operation, as well as the load on the vehicle.

3.5.1 Compartmentalized Vehicles

The alternative of compartmentalized vehicles is the policy generally in effect in the petroleum industry today. Vehicles tend to be divided into 2 to 6 compartments. In the simulation, only two compartments are considered, one for regular and one for premium gasoline. Further, the assignment of a given compartment to a product type is fixed throughout the simulation. These simplifications are needed to avoid difficulties in compartment allocation which may arise if multi-station routes are developed. An objective of the simulation is to determine the best size ratios for these compartments for a fixed total vehicle capacity of 8000 gallons.

Within the case of compartmentalized vehicles, the assumed operating procedure is that delivery of one product to a given station requires delivery of the second product. This simplification is made to facilitate the development of multi-station routes also. A parameter to be investigated in the simulation is termed the delivery factor. This factor determines the minimum percentage of a station's order quantity for a given product which can be delivered, rather than the
full order. With a reorder level of 25% of station storage tank capacity, order sizes can be large in comparison to compartment sizes. Thus a single delivery may not meet all of a station's requirements. If, however, this single delivery comprises a fraction of the full order size equal to or in excess of the delivery factor, a second delivery will not be made. The effect of shorting the original order is that of increasing order frequency. It may not increase the frequency of trips to the location, as only one, rather than two trips will be made to the station in the current day. Second deliveries are not made for priority orders.

If an order completely fills its assigned compartment, the order will be delivered on a single station route. With the addition of a second station to the route, both products could not be delivered to the second station. Any order must be of size sufficient to fill the assigned compartment to a specified fraction of its total capacity. This fraction is called the utilization factor. With the large order sizes resulting from a 25% reorder level, this factor does not come into effect except on second deliveries to a station in a current day. It is not varied in the simulation case studies investigated, being set at 10% of truck capacity.

3.5.2 Non-compartmentalized Vehicles

In this alternative, separate compartments are not used for each product. A vehicle on a specific trip will deliver only regular or premium gasoline. In this case, single order sizes are not as likely
to fill the entire vehicle, therefore more multi-station routes should be formed. There are considerations which are expected to make this alternative inferior. The constant times for loading and unloading will be encountered more often, as the number of loadings and unloadings will increase with separate routes for regular and premium gasoline. The possible improvement over compartmentalized vehicles may stem from the capacity to deliver increased order sizes, thereby decreasing the number of deliveries to a station.

3.5.3 Summary of Alternatives and Parameters Investigated.

1. Compartmentalized Vehicles
   A. Compartment sizes
   B. Delivery factor

2. Non-compartmentalized vehicles
   A. Utilization factor

3.5.4. Data Management for Vehicles

The vehicles comprise a second major entity group in the simulation, with statistics gathered pertinent to these entities, and parameters associated with them governing various aspects of simulated system operation. A reference matrix is established in the simulation program similar to that set up for the stations. This matrix, VMRM, is the vehicle master reference matrix. The index J refers to the storage position in the matrix and not necessarily the vehicle identification number.
VMRM(J,1) - Vehicle identification number.
VMRM(J,2) - Maximum number of hours per day for which the vehicle is available.
VMRM(J,3) - Maximum allowable trip time for a single trip.
VMRM(J,4) - Number of compartments on the vehicle.
VMRM(J,5) - In the program for compartmentalized vehicles, capacity in gallons of the regular gasoline compartment.
   In the program for non-compartmentalized vehicles, vehicle capacity in gallons.
VMRM(J,6) - In the program for compartmentalized vehicles, the capacity in gallons of the premium compartment.
   Unused in the program for non-compartmentalized vehicles.
VMRM(J,7) - Normal shift length in hours.
VMRM(J,8) - Cumulative total hours of overtime.
VMRM(J,9) - Cumulative total number of trips.
VMRM(J,10) - Cumulative total vehicle mileage.
VMRM(J,11) - Cumulative total gallons delivered.
VMRM(J,12) - Cumulative total number of hours in service.
VMRM(J,13) - Cumulative total number of trips with excess load.
VMRM(J,14) - Total hours in service in a current day.
VMRM(J,15) - Cumulative total gallons of excess load.
3.6 Dispatching

The length of the normal shift and allowable overtime are possible parameters for investigation. In this study, however, adequate values are to be determined to allow delivery of product with an acceptable number of lost sales. Other factors will receive more thorough investigation. The number of vehicles is also to be determined in this manner.

The dispatching of orders is carried out utilizing information in the order file and priority list. Initially, all orders are allocated to single station routes. Those stations which have priority orders will be served by single station routes as well as those having orders completely filling one or both compartments, or in the case of non-compartmentalized vehicles, the entire vehicle. In dispatching with a given number of vehicles, there is a daily availability of vehicles, in hours, which cannot be exceeded. This availability is the sum of the shift length plus the allowable overtime multiplied by the number of shifts. Any single route cannot exceed the length of one shift plus the allowable overtime, nor may the total time of all routes assigned to a single vehicle exceed that vehicle's availability. In the initial allocation, route times are tabulated, and the total route time for each vehicle is monitored. If the total availability of all vehicles is exceeded, the allocation halts, and all remaining orders will be deferred until the next day. They are rescheduled as priority orders, and their quantities increased according to updated inventory status. The restrictions summarized are:
1. Individual route time restriction.
   \[ \text{RTTIM} \leq \text{VMRM}(J,3) \]
   \[ \text{RTTIM} = \text{Total route time}. \]
   \[ \text{VMRM}(J,3) = \text{Length of single shift + maximum allowable} \]
   \[ \text{overtime for one shift}. \]

2. Restriction on vehicle daily usage.
   \[ \text{VMRM}(J,14) + \text{RTTIM} \leq \text{VMRM}(J,2) \]
   \[ \text{VMRM}(J,14) = \text{The total time of all routes permanently assign-} \]
   \[ \text{ed to vehicle J in the current day}. \]
   \[ \text{VMRM}(J,2) = \text{The maximum daily availability of vehicle J}. \]

3. Restriction on vehicle load.
   \[ \text{TLOAD}(1,J) \leq \text{VMRM}(J,5) \]
   \[ \text{TLOAD}(2,J) \leq \text{VMRM}(J,6) \]
   \[ \text{TLOAD}(1,J) = \text{Regular load quantity}. \]
   \[ \text{TLOAD}(2,J) = \text{Premium load quantity}. \]
   \[ \text{VMRM}(J,5) = \text{Regular compartment capacity}. \]
   \[ \text{VMRM}(J,6) = \text{Premium compartment capacity}. \]
   In the case of the non-compartmentalized vehicles, the first
   equation only is needed.
   \[ \text{TLOAD}(J) \leq \text{VMRM}(J,5) \]
   \[ \text{TLOAD}(J) = \text{Load quantity}. \]
   \[ \text{VMRM}(J,5) = \text{Vehicle capacity}. \]

   In this initial allocation, load size for a given product, \( I \), may
   be less than the order size. In that case, a full compartment or vehicle
load will be shipped. If the shipment does not comprise the fraction of the full order specified by the utilization factor, a second delivery will be made, i.e.,

\[
\text{if } \text{OFIL}(I,J) \cdot DF \geq TLOAD(I,J).
\]

One delivery in the quantity corresponding to the compartment size (vehicle size in non-compartmentalized case) is shipped, and a second delivery of the remaining order is placed in the order file. Priority orders are not considered for second deliveries in a current day. As each single trip allocation is made, the vehicle daily time in service, VMRM(J,14), is updated by the addition of the time of the new route:

\[
\text{VMRM}(J,14) = \text{VMRM}(J,14) + \text{RTTIM}
\]

3.6.1 Multi-station Routes

Although there should not be a large number of multi-station routes formed with the order sizes involved here, when the possibility arises, the routing should be carried out in a reasonable manner. Rather than establish some arbitrary rules, the algorithm of Clarke and Wright is modified and incorporated in the simulation (Cochran 3). This is a simple but effective algorithm which produces routes comparable to those produced by human dispatchers, but with sufficient speed to be used in the simulation. Modifications are made to further increase its speed and to allow it to accept compartmentalized vehicles. The algorithm utilizes a "savings" concept in developing routes to serve a given set of stations. The maximum mileage a vehicle would have to
travel in serving two stations occurs in the case where the stations are served individually. The total mileage in this case is

\[ M = 2d_{T,1} + 2d_{T,2} \]

where \( M \) = total mileage
\[ d_{T,1} = \text{distance from the terminal to station 1.} \]
\[ d_{T,2} = \text{distance from the terminal to station 2.} \]

If it is possible to serve these stations together on a route, the distance becomes

\[ M = d_{T,1} + d_{T,2} + d_{1,2} \]

where \( d_{1,2} = \text{distance from station 1 to station 2.} \)

Provided that \( d_{1,2} < d_{T,1} + d_{T,2} \), a savings in the distance results from joining these two points together, that savings being expressable as

\[ S_{1,2} = d_{T,1} + d_{T,2} - d_{1,2} \]

Note that these savings may be expressed in terms of time or costs as well as distances. The costs are assumed constant for a link between two stations, regardless of the direction of travel, thus only a lower triangular savings matrix is all that is needed to express all possible savings. The savings are calculated for the combinations of stations in the delivery network, and the Clarke and Wright procedure proceeds in creating a solution by sequentially examining the maximum savings among the combinations. At each stage of the algorithm, the pair of points yielding maximum savings is checked for feasibility. If the
pair may be feasibly linked, an expanded route is formed. Note that the pair of stations considered may be the endpoints of two multi-station routes. In any case, the combined loads of the two routes are examined to see if they exceed vehicle capacity. If so, the link is not formed. Other restrictions checked include the requirements that both of the stations have at least one link to the terminal, and that they not be on the same route. This prevents looping, the formation of a closed route with no link to the terminal.

Within the simulation, savings are calculated on the basis of total link transit cost. For a given link, the total transit cost is calculated by

\[ CM(I,J) = CD \cdot TIM(I,J) + (CMT + COP) \cdot DIS(I,J) \]

where
- \( CM(I,J) \) = total link transit cost.
- \( CD \) = driver's hourly wages.
- \( TIM(I,J) \) = link transit time in hours.
- \( CMT \) = vehicle maintenance cost per mile.
- \( COP \) = vehicle operating cost per mile.
- \( DIS(I,J) \) = length of link in miles.

Again, transit costs are assumed independent of load. The algorithm removes a savings from consideration once it is selected or found non-feasible. The remaining savings are examined iteratively, until no savings remain greater than zero which represent feasible links.

3.6.2 Extension to Compartmentalized Vehicles

Within the simulation case involving compartmentalized vehicles,
this algorithm has been modified to accept the compartmentalization. An additional feasibility check is imposed in that the combined loads of both routes, for both products are checked against their assigned compartments. If the combined load for either product exceeds the available compartment capacity, it may be reduced. The same delivery factor applied to single station routes again dictates the maximum allowable reduction. If the combination of two routes yields a load quantity for one of the two products which cannot meet the delivery factor criteria, the routes are not combined. Note that the delivery of both products to a specific station is bound to one vehicle in the multi-station routing, as it was in the single station routes.

3.6.3 Computational Modifications

In the simulated system, there are twenty-five stations. All of these stations will not be scheduled for delivery in any given day. To avoid searching the large savings matrix which is generated with twenty-five stations, indirect indexing is used. A dummy vector is set up in the program to store the savings matrix index numbers for each station in the delivery file on a given day. Rather than search the savings matrix in a loop in the program which varies its indices directly, a loop is established which varies the reference number of the dummy vector. The contents of the dummy vector cell then contains the proper savings matrix index. By example, if stations 2,7,8,10, and 13 are to receive orders in a given day, the dummy vector will contain these entries:

\[
\begin{array}{ccccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & \ldots & 24 & 25 \\
\text{INIDX} & 2 & 7 & 8 & 10 & 13 & 0 & \ldots & 0 & 0 \\
\end{array}
\]
The number of entries in this vector is stored as JDX. This vector is established prior to the single station route formation, thus the order of assignment to single station routes is the order of the entries in this vector. The latter stations in the assignment are more likely to have their orders deferred if equipment availability is less than requirements. The savings matrix is represented as a lower triangular matrix. In searching for the maximum savings among a number of possible combinations of five points the original algorithm would vary the direct indices of $\text{SAV}(I,J), 1 \leq J \leq 4, (J + 1) \leq I \leq 5$, $I$ varied most rapidly. With the indirect index, $\text{SAV}((\text{INIDX}(I), \text{INIDX}(J)))$ would be indexed, with $1 \leq J \leq (\text{JDX}-1), (J + 1) \leq I \leq \text{JDX}$, $I$ varied most rapidly. Thus the columns and rows corresponding to entries in the indirect index vector are the only ones searched. This saves a lot of computation, particularly if only a few of the total number of stations are in a given day's order file.

A second modification is made in the method of keeping track of routes. A directional chain matrix is used rather than the method used by Cochran (3,19). This method allows quicker tabulation of final route statistics. The chain matrix is initialized as:

<table>
<thead>
<tr>
<th>Station</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>5</td>
<td>T</td>
<td>T</td>
</tr>
</tbody>
</table>
where T indicates a link to the terminal (−9 is used in the program to indicate a terminal link). As a route is formed, by example, 3 and 5 are linked, the updated matrix becomes:

<table>
<thead>
<tr>
<th>Station</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>T</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>T</td>
</tr>
</tbody>
</table>

The actual direction of the routes is of no concern here, however two points may be linked which have terminal links under the same column. In this case one of the routes must be reversed.

Example:

If the two routes exist, (T-4-5-7-3-T) and (T-6-9-10-8-T):

<table>
<thead>
<tr>
<th>Station</th>
<th>From</th>
<th>To</th>
<th>Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(T-4-5-7-3-T)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(T-6-9-10-8-T)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>T</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
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<td>T</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>
and the maximum savings results from linking stations 4 and 6, it must be determined that the flow will be from 4 to 6, or from 6 to 4. The direction does not really matter, however in this case both points are indicated as being the starting points of their routes. To create the new route, either route may be reversed. Reversing the route of station 6 yields:

<table>
<thead>
<tr>
<th>Station</th>
<th>From</th>
<th>To</th>
<th>(T-4-5-7-3-T) (T-8-10-9-6-T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>T</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

The entries in each column for the points on this route are merely exchanged. Thus in linking 6 and 4, the matrix becomes:
The new route being (T-8-10-9-6-4-5-7-3-T).

In compiling statistics, all that need be done is begin with any point in the "from" column with a terminal link and proceed to the next point as indicated in the "to" column, until a terminal link is encountered in that column. In the program, a matrix IROUT contains the directional chains, as well as route number designations and counters for the number of terminal links associated with each point.

3.6.4 Limitations

Within the routing algorithm, all orders are initially assigned to the vehicles as single station routes. This requires more time than is required if some of the stations may later be placed on multi-station routes. If sufficient vehicle time is not available to serve all stations individually, the later stations assigned in the initial allocation may be
dropped from the daily order file, becoming priority orders the next
day. Subsequent reduction in the total required time may allow these
stations to be served in the current day, however they will not be
reconsidered. This is a required logic simplification, decreasing the
routing efficiency. It is necessary because in the simulation, there
must be no chance of exceeding actual vehicle availability. Within the
Clarke and Wright algorithm as modified by Cochran (3,33), dummy ve-
hicles were created in the initial allocation to provide for this.
There is a possibility with this technique that the dummy vehicle may
be left in the final solution. This cannot be permitted in the simu-
lation.

3.6.5 Summary of Modified Algorithm

1. Savings in terms of costs are calculated.

\[ \text{SAV}(I,J) = \text{CM}(T,I) + \text{CM}(T,J) - \text{CM}(I,J) \]

\[ \text{SAV}(I,J) = \text{Savings obtained by linking points } I \text{ and } J. \]

\[ \text{CM}(I,J) = \text{Cost of transit on link } I-J. \]

\[ \text{CM}(T,I) = \text{Cost of transit on link } T-I. \]

\[ \text{CM}(T,J) = \text{Cost of transit on link } T-J. \]

2. These savings are searched for the maximum savings. The
combination yielding the maximum is then checked for feasi-
bility:

A. They must each have at least one link to the terminal.

\[ \text{IROUT}(I,1) \geq 1 \]

\[ \text{IROUT}(J,1) \geq 1 \]

where \( \text{IROUT}(I,1) \) = number of links between station I and
the terminal.
IROUT(J,1) = number of links between station J and the terminal.

B. The two stations must not be on the same route.

IROUT(I,4) ≠ IROUT(J,4)

where IROUT(I,4) = route number of station I before linking.
IROUT(J,4) = route number of station J before linking.

C. The total loads must not exceed the compartment capacity.

TLOAD(1,I) + TLOAD(1,J) ≤ VMRM(K,5)

where TLOAD(1,I) = regular load for the route of station I before linking.
TLOAD(1,J) = regular load of the route of station J before linking.
VMRM(K,5) = regular compartment size, vehicle K.

Likewise for premium,

TLOAD(2,I) + TLOAD(2,J) ≤ VMRM(K,6)

where TLOAD(2,I) = premium load for the route of station I before linking.
TLOAD(2,J) = premium load of the route of station J before linking.
VMRM(K,6) = premium compartment size, vehicle K.

In the case of non-compartmentalized vehicles, the load size is compared to the total vehicle capacity.

Note that the original order quantities may be reduced in order to combine two routes, but must remain a fraction of original order size at least as great as the specified delivery factor.
D. The total route time must not exceed the length of a shift plus the maximum overtime.

\[ \text{TRTIM} \leq \text{VMRM}(K,3) \]

where TRTIM = the total route time of the proposed new route.

\[ \text{VMRM}(K,3) = \text{maximum allowable route length for vehicle } K. \]

3. At each linking, the route times, lengths, and loads are updated, as are the vehicle statistics.

3.7 Delivery of Product

As deliveries are made, the actual inventory status after delivery becomes known to the dispatcher. The predicted status is corrected, however no corrective modification is made to the forecast mechanism. There is the possibility that a station may actually require more product than is scheduled for delivery. On single station routes, this extra demand cannot be satisfied. It will force a new order to be scheduled more quickly, however, as the updated predicted status will reflect this occurrence. If the station cannot accept the scheduled load, however, the total gallons of excess load on the vehicle are recorded as a system total.

With multi-station routes, stations with actual demands above the scheduled load will receive only the amount scheduled unless a prior station could not accept its scheduled load. Any excess load is distributed among subsequent stations on the route to avoid the excess load condition. If, at the end of a route, there is still excess load on the vehicle, it is recorded.
3.8 Statistics Gathered in Routing and Delivery

Certain statistics pertaining to the vehicles operations are tabulated and reported in routing, as well as the pertinent inventory related statistics, for use as indicators of operational efficiency. These include:

1. Total number of trips.
2. Average number of trips per day.
3. Average trip length, in miles.
4. Average trip time.
5. Average gallons delivered per trip.
6. Vehicle operating cost.
7. Vehicle driver costs.
8. Vehicle maintainence cost.
9. Total vehicle related costs.
10. Total idle time.
11. Total overtime.
12. Average transportation cost per gallon delivered.

A sample printout in Table 3.1 illustrates these statistics.
### Model Coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
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<td>38.2746</td>
<td>28.0347</td>
<td>30.3233</td>
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<td>5.6394</td>
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<td>-6.0477</td>
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<td>0.00</td>
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**Note:** The table represents the cost matrix for various items, with each cell indicating the cost in monetary units. The savings matrix is derived from the cost matrix, showing potential savings in similar units.
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SIMULATED TIME 28
REPORT PERIOD 1

VEHICLE STATISTICS

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<th>VEHICLE NUMBER</th>
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<th>AVERAGE TRIP LENGTH</th>
<th>AVERAGE TIME PER TRIP</th>
<th>AVERAGE GALLONS DELIVERED PER TRIP</th>
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<th>NUMBER OF TRIPS WITH EXCESS LOAD</th>
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<th>VEHICLE MAINTENANCE COST</th>
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TOTAL CSTATE TIME 26.5 HOURS
TOTAL IDLE TIME 47.7 HOURS
TOTAL GALLONS EXCESS LOAD 243.8 GALLONS
AVERAGE TRANSPORTATION COST 0.00197 PER GALLON DELIVERED
## STATION STATISTICS

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<th>AVERAGE ORDER SIZE</th>
<th>AVERAGE INVENTORY LEVEL</th>
<th>STATION INVENTORY CARRYING</th>
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AVERAGE TOTAL COST 2.2030 PER GALLON SOLD
NUMBER OF DELIVERED ORDERS
LCST SALES REGULAR 0.0 GALLONS
LCST SALES PREMIUM 0.0 GALLONS

123
CHAPTER IV

EXPERIMENTATION, RESULTS, AND EXTENSIONS

4.1 Stability Checks

4.1.1 Seed Values

The error component of the forecast is generated randomly, requiring a seed number to initialize the random number generator. It is known that each seed number generates a different set of random numbers, and each series of random numbers will vary from the others in qualities such as autocorrelation and the degree of fit to the desired distribution. The effect of the differences in series of random numbers upon the generated demands is of interest, as these demands dictate the response of the system. Before any experimentation can be carried out, the stability of the generated demands with respect to changes in seed values must be examined. Figures 4.1 and 4.2 are plots of average daily demands for regular gasoline generated by two different seed values. Figures 4.3 and 4.4 are plots of average premium demands from the same set of seed values. The demand patterns show the expected seasonal effects and the effects of the quadratic trend component which are present in most of the models. The patterns for both of the seed values are similar, relative differences between the average demands being small. This implies that the statistics for a given case study should have a small standard error with respect to the random variability of the demand. The seed values are varied between case studies in the experimentation. The tables of the results, Tables 4.4 - 4.7, report the
average daily demands for both products over the 12 months. Between all of the runs, there is very little difference in the generated average demands, giving further evidence that the simulation is stable with respect to the seed values.

4.1.2 Starting Conditions

It would be unrealistic to start the simulation with all of the station inventory levels at zero. The delivery system would be overloaded, and likely require a long time to reach a point where the operations would be "normal". It is more desirable to start the stations in various stages of inventory depletion, to avoid large numbers of orders in the early time periods of the simulation. The reorder point and the operational efficiency of the delivery system should determine a level of average inventory toward which the system will tend. The length of time required for this level to be reached must be known, as statistics from beyond this point are valid indicators of normal system operation, while those prior to this point reflect system operation under abnormal conditions. In initializing the inventory levels, a random number from the interval (0,1) is multiplied by the difference between reorder level and tank capacity, for each product at each station. This value, added to the reorder level, yields the starting condition:

\[
\begin{align*}
SMRM(J,8) &= SMRM(J,4) + N \cdot (SMRM(J,2) - SMRM(J,4)) \\
SMRM(J,9) &= SMRM(J,5) + N \cdot (SMRM(J,3) - SMRM(J,5))
\end{align*}
\]

where \( SMRM(J,8) \) = starting actual inventory level, regular gasoline, at station \( J \).
SMRM(J,4) = reorder level, regular gasoline, station J.
SMRM(J,2) = storage tank capacity, regular gasoline, station J.

N = a random number from the range (0,1).

SMRM(J,9) = starting actual inventory level, premium gasoline, station J.
SMRM(J,5) = reorder level, premium gasoline, station J.
SMRM(J,3) = storage tank capacity, premium gasoline, station J.

The forecast inventory status is initialized at this same value. A second stability test must be made to determine if different initial levels of inventory have a noticable effect upon the period of time required for the system to reach normal operating conditions. Two sets of starting conditions, presented in Tables 4.1 and 4.2, are tested. The plots in Figures 4.5 and 4.6 represent the resulting average inventory levels for regular gasoline, and the plots in Figures 4.7 and 4.8 represent the average inventory levels for premium gasoline. The initial levels for regular gasoline appear to be higher than the normal level, under both sets of initial conditions. The initial levels for premium appear lower than normal levels under both sets of starting conditions. After six months of simulated time, the inventory levels are tending to become stable. This indicates a "warm up" period of six months is needed to allow the system to overcome the effects of initial starting conditions. Statistics should not be considered from this period of time, as they reflect abnormal operating conditions.
4.1.3 Run Length

With the first six months of simulated time required for the system to overcome the starting conditions, the total length of the runs must be determined. With strong quadratic components in the models, it was noted in Chapter 2 that the simulation should not extend beyond the period of time represented by the data used in developing the models. Further, looking back to Figures 4.1 - 4.4, the graphs of average daily demands, the quadratic effect becomes dominant after the eighteenth report period. The demands do not return to a lower base level after July as they do in the first simulated year. Further, the total cost begins to increase rapidly after the eighteenth month, Figures 4.9 - 4.10, indicating more strain being put on the system fleet capacity due to the "runaway" demand. This last six month period, from month 18 to month 24, yields results which reflect the need for a change in fleet characteristics. Future investment alternatives are not an objective of the investigation, a fixed fleet description being assumed. The simulation should not be run beyond 18 months, leaving a full 12 months of simulated time for investigation. This should be adequate for studying alternatives, as all seasonal effects will be present in this length of time.

4.2 Parameters Investigated

4.2.1 Reporting Period

The program has a flexible report interval. This allows the system to be debugged on a daily basis with a relatively small computer cost,
and studied over longer time basis to reduce the variations of the statistics. A proper report interval must be chosen to determine how often statistics will be printed out during the simulation. Daily printouts would generate statistics with large day to day variations for individual stations, as no stations receive a delivery every day. Weekly statistics would alleviate this problem, however a 28 day reporting would provide enough detail with regard to the seasonal variation in system demands. During this period of time, every station should receive a delivery. Further, 28 days is an integral number of weeks, providing a balanced effect of the day factors in all report periods. This report period does not correspond to the normal months of a year, with 13 of the 28 day periods in a year rather than 12 months. There is no obvious advantage to having report periods in exact correspondence with the months of the year, as the objective is not to reproduce accounting data based on monthly report intervals. The objective is to gain an understanding of the fundamental process. The correspondence of the simulation report dated to dates of the simulated years are presented in Table 4.3.

4.2.2 Parameters

As the simulation is presently written, there are several possible parameters which may be investigated. They include:

1. Vehicle availability.
   (a) Number of vehicles.
   (b) Shift length.
(c) Number of shifts.
(d) Allowable daily overtime.

2. Reorder levels.
3. Utilization factor.
4. Delivery factor.
5. Compartment size ratios.

In addition, there are the two major modes of operation, compartmentalized vehicles and non-compartmentalized vehicles. Within the available time, it is not possible to investigate all of these parameters in detail. As a result, some of them are to be fixed throughout all of the simulation runs.

From preliminary runs, the number of vehicles does not appear to be worthwhile as an investigated parameter. No more than two vehicles are ever required to deliver the product. In using two vehicles, there is still a lot of idle time. Reducing the vehicles to one then requires determination of the proper shift length and allowable overtime. The normal shift length used throughout the simulation is eight hours with two hours overtime. The tables of the results of the runs, Tables 4.4 - 4.7, indicate that there is considerable overtime used, with idle time during the normal shift.

In explaining this effect, the day factors' contribution to the demand pattern should be examined. This effect is calculated for a given day by taking the sum of the day factors for each model type multiplied by the number of stations having that model type.
EFFECTS OF DAY FACTORS

(In Gallons)

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<td>Sunday Factor</td>
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Thus the high volume days, Saturday and Sunday, occur at the time when the advanced planning horizon is used. This generates a large number of orders to be delivered on Saturdays. In delivering these orders, overtime is needed. Some of the orders may be deferred until Monday, at which time they become priority orders. With Monday's demand level appearing to be lower, there is a chance to catch up on deliveries. By Tuesdays and Wednesdays, which are lower in sales, there can be idle time occurring from fewer orders being placed. Corrective action could include the consideration of Sunday delivery operations, or the use of an extended planning horizon, discussed in the section on recommendations.

The number of vehicles required to serve a given volume of demand will be affected by the distances between the terminal and the stations, increased distances requiring longer travel times, thus more vehicle availability. The hypothesized system is idealized; such concentration
of demand in an area the size of Tulsa, among only twenty-five stations, would be rare. A larger area such as Los Angeles may be more realistic, and the distances involved would be greater.

Within the simulation program as it exists, an eight hour shift with two hours overtime yields acceptable results. Other parameters such as the delivery factor and compartment size will affect the number of orders placed, deliveries made, and the resulting time requirements placed on the vehicles. After these other parameters have been reduced to a limited range of values, experimentation will be done with shift lengths and overtime to find the cost of handling the overloads on Saturday.

The reorder level is to be set at 25% of storage tank capacity at each site throughout this simulation for the practical operating considerations of avoiding the sludge and water accumulations in the tanks. This reorder level will generate large order sizes. Thus the utilization factor will be fixed at 10% during all of the experimentation, as it should rarely become a restrictive factor in dispatching.

The two primary parameters to be investigated are the compartment size ratios in the compartmentalized vehicle mode of operation, and the delivery factor in both modes. These factors are felt to have the most direct effect on the efficiency of the delivery system. The delivery factor provides a means of adjusting the order size below that determined by the reorder level, if this would provide for better vehicle utilization. It will prevent second deliveries from being sent to a station in a current day, when the first delivery is at least a specified fraction of
the whole order. Compartment sizes determine the upper limit on an individual delivery. The ratio of the deliveries of two products should be nearly the same as the ratio of demand for the two products to enable synchronization of orders for the products.

4.2.3 Parameter Ranges

The compartment sizes to be investigated are all within close range of the ratio of average premium sales to average regular sales over the two years of historical data. The ratio is approximately 3 to 5. The compartment sizes, premium/regular, are thus 2500/5500, 3000/5000, and 3500/4500. Preliminary values of the delivery factor are .9, .8, and .7. Subsequent experimentation and results show that the 2500/5500 compartment ratio is consistently inferior to the other two, thus extended experimentation with this case is dropped and the delivery factors for the other two cases are extended to .6 and .5. Likewise, preliminary investigation of the non-compartmentalized vehicles indicate that this mode of operation is inferior. The effect of the delivery factor for the non-compartmentalized vehicles is investigated at .8 and .9.

4.3 Results

4.3.1 Compartmentalized vehicles

All of the results for the three compartment size ratios are presented in Tables 4.4, 4.5, and 4.6. For the more important indicators, graphs facilitate the discussion of the results. Average load per trip gives an indication of the utilization of vehicle capacity. It is plotted in Figure 4.11 against the delivery factor. The maximum average
load per trip is attained with the compartment ratio 3000/5000. This ratio is closest to the average sales ratio over the two years history. The peak value is 7325 gallons per trip, with a delivery factor of .6. The 3500/4500 compartment split yields comparable results, however is slightly less in average load size, with 7210 gallons per trip. Both of the curves for these two cases have a similar shape. The average load sizes increase rapidly as the delivery factor is reduced from .9 to .6, where the peak in average load size is attained. The largest average load size for the 3500/4500 ratio is 90% of the vehicle load capacity. The largest average load size for the 3000/5000 ratio is 91% of the vehicle capacity, not a significant difference. The 2500/5500 compartment ratio is inferior to the other two in all cases run, its highest average load size being only 6003 gallons, 75% of the vehicle capacity.

In examining the average number of trips made in each case, Figure 4.12, the 3500/4500 and 3000/5000 cases yield nearly the same values, with the 2500/5500 case requiring 20% more trips. Comparing this with the number of deliveries, also in Figure 4.12, the order sizes are limiting the possibility for multi-station routing. The difference between the number of trips and the number of deliveries gives an indication of how many deliveries are made on multi-station routes:
Difference Between Number of Trips
and Number of Deliveries

<table>
<thead>
<tr>
<th>Delivery Factor</th>
<th>3500/4500</th>
<th>3000/5000</th>
<th>2500/5500</th>
</tr>
</thead>
<tbody>
<tr>
<td>.5</td>
<td>8</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>.6</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>.7</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>.8</td>
<td>5</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>.9</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Note that both the 3000/5000 and 3500/4500 compartment size ratios experience the minimum number of deliveries at a delivery factor of .6, and the number of deliveries increases at a delivery factor of .5, while the number of trips for both compartment ratios levels out between .5 and .6. This is an indication that more vehicle capacity is freed from the initial allocation of single trips to allow the scheduling of multi-station routes.

The 2500/5500 compartment ratio makes more trips and deliveries. The number of multi-station routes is comparable to the other cases, however. The bound on the premium compartment size is forcing more frequent delivery and more second deliveries in a current day. This is further supported by the plot of average delivery sizes versus the delivery factors, Figures 4.13 and 4.14.

In the Figure 4.13, the compartment ratio 2500/5500 has a smaller average delivery size for regular gasoline than the other two ratios,
which actually have smaller compartments for regular. Thus the vehicle is being forced to make second deliveries to fill the premium orders, at all of the delivery factors investigated. These second trips are made with empty or partially filled regular compartments. (Recall that the number of trips for this case is 20% higher than the other two alternatives, for all delivery factors.) The 3000/5000 case reaches the highest average delivery size at a delivery factor of .6, however the 3500/4500 ratio does not yield significantly different results.

The average premium delivery size, in Figure 4.14, shows similar results. Here the restraint upon the premium delivery size is the compartment size itself for the 2500/5500 ratio. The highest average delivery size is obtained with the 3500/4500 ratio, at a delivery factor of .6.

Turning now to the plots of the number of expedited orders versus the delivery factor and the number of deferred orders versus the delivery factor, Figure 4.15, the trend in these plots is generally the same as that in the others. One obvious difference in operational efficiency is that the 3500/4500 ratio has fewer expedited orders and fewer deferred orders for the delivery factors .7 and .8, where the 3000/5000 ratio has been consistently the better case in terms of the previously discussed indicators. The minimum occurs at a delivery factor of .7 for the 3500/4500 ratio, where previously best values had been found at .6. With the 3000/5000 ratio, the minimum number of deferred and expedited orders occurs at a delivery factor of .6.
The two plots of lost sales versus delivery factor, Figure 4.16, shows an effect of changing compartment ratios; the system will "favor" the delivery of one product over the other. With the 2500/5500 ratio, there are more premium sales lost than regular. The 3500/4500 ratio results in consistently fewer lost sales for premium, and the 3000/5000 ratio has results between these two extremes.

By contrast, more regular lost sales result with the 3500/4500 ratio, fewer with the 2500/5500, however, at delivery factors of .7 and .9, the 3000/5000 ratio is superior to the 2500/5500. The total lost sales are:

<table>
<thead>
<tr>
<th>Delivery Factor</th>
<th>3500/4500</th>
<th>3000/5000</th>
<th>2500/5500</th>
</tr>
</thead>
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<tr>
<td>.5</td>
<td>12934</td>
<td>13084</td>
<td>-</td>
</tr>
<tr>
<td>.6</td>
<td>7469</td>
<td>5830</td>
<td>-</td>
</tr>
<tr>
<td>.7</td>
<td>4817</td>
<td>5856</td>
<td>9326</td>
</tr>
<tr>
<td>.8</td>
<td>7442</td>
<td>9537</td>
<td>7603</td>
</tr>
<tr>
<td>.9</td>
<td>12772</td>
<td>8410</td>
<td>18702</td>
</tr>
</tbody>
</table>

Total Lost Sales

Note that the average daily demands (Tables 4.4 - 4.6) are stable in the range of 25,300 gallons per day. Over the 28 day reporting period, this is a total demand of 710,000 gallons. The maximum lost sales is 18,700 gallons, about 2.6% of total demand. On the other hand, the best policy with respect to lost sales results in 4817 gallons lost, or .68%. Again, the majority of lost sales shifts to regular or premium, depending
on compartment size ratios.

In all of the cases with an eight hour normal shift and two hours overtime, monthly availability of the vehicles, in hours, is 240 hours. The idle time is counted only during the normal shift, thus is the number of idle hours out of 192 normal shift hours. The idle time is plotted in Figure 4.17. These plots demonstrate poor vehicle utilization with respect to time, for every policy examined. Overtime is required in every case, while there are idle hours during the normal shift. Thus the greater number of orders occuring on Saturday due to the extended planning horizons requires overtime for delivery.

The total costs are plotted in Figure 4.18. These costs represent the total available vehicle costs, operating costs, maintenance costs, drivers' wages, the costs of taxes, insurance, and licensing, and the costs of carrying inventory. The 3000/5000 ratio yields the lowest average monthly cost, at a delivery factor of .6, $1193.10. There are several alternatives which are in the range of this figure:

<table>
<thead>
<tr>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery Factor</td>
</tr>
<tr>
<td>.5</td>
</tr>
<tr>
<td>.6</td>
</tr>
<tr>
<td>.7</td>
</tr>
</tbody>
</table>

The 3000/5000 ratio is noted to be consistently lower than the 3500/4500 ratio for corresponding delivery factors. The 2500/5500 ratio results
are significantly worse than the other two.

4.3.2 Alleviation of Lost Sales

The 3000/5000 compartment ratio and the 3500/4500 ratio are very close in most of the results discussed. The proper delivery factor varies from .6 to .7, depending on the particular indicator examined. The 3000/5000 ratio may prove more acceptable because of a more favorable balance between lost sales of the two products. This ratio is chosen for further experimentation with shift lengths to determine if increasing vehicle availability is a reasonable way to reduce lost sales. Table 4.5 shows the results of the two final runs. A normal shift length of ten hours with two hours overtime reduces lost sales to 1567 gallons, compared to the best run with an eight hour shift, two hours overtime, of 5830 gallons. This is a reduction of 37%. The cost is increased from $1423.29 average monthly, to a monthly average cost of $1580.87, an increase of $157.58 or 11%.

Decreasing the normal shift to eight hours and allowing a maximum of four hours overtime results in lost sales of the same proportion, 1464 gallons per month, at a total cost of $1509.91 average monthly. This increase is only $86.62. Overtime in the eight hour shift case is 24.7 hours compared to 5.7 hours for the ten hour shift.

An alternative method of reducing lost sales is to increase the reorder level. The carrying costs for the system are small, and this increase would not likely be as costly as increasing the vehicle availability. If the reorder point is set high enough, it may generate small order sizes, and increase the delivery cost by increasing order frequency.
4.3.3 Non-Compartmentalized Vehicles

The results of this mode of operation, Table 4.7, are evidently inferior to the compartmentalized vehicles. Restricted to only one vehicle, as the other cases are, the number of lost sales is significantly greater than any of the compartmentalized vehicle cases. The number of trips is greater, and the number of deferred orders at an unacceptable level. Increased time required to service the stations, due to the increased number of separate loadings and unloadings far outweighs any advantage resulting from possible increased delivery sizes at individual stations. Although the increased delivery sizes exist, the average gallons per trip is lower. A given trip must rely strictly on regular or premium orders to fill the vehicle. This can result in trips with partially loaded vehicles, reducing the average load size. All indicators considered, this mode of operation is rejected.

4.4 Recommendations

The alternative operating procedures examined herein do not exhaust all possibilities. Several of the parameters which could have been varied were not. Those that were examined were limited in the ranges of their values by time and allocated computer resources. Several shortcomings of the existing simulation have been demonstrated, and these areas should be improved. As a guide to the possible direction of future research, several recommendations are made.
4.4.1 Improved Demand Models

Looking at the results of Chapter 2, the demand models used in this simulation leave quite a bit of room for improvement. The primary question is the degree of improvement attainable with the data. Only historical sales data has been provided.

Analysis of the data by techniques used in Chapter 2 is costly in terms of computer time, and one should bear in mind how much return is associated with improving these models. More accurate models would reduce the standard errors of estimate, allowing a decrease in the expected error between the actual and forecast processes. This should alleviate some of the priority orders and allow for more accurate determination of order sizes in the normal order procedure. The maximum improvement can be estimated by merely setting the standard errors of estimate to zero for the present models and observing the improvements in system operation. From this information, one could judge the benefit in improving the models.

4.4.2 Extended Planning Horizon

The utilization of the available vehicle fleet could be improved by expanding the planning horizon to several days or a week. The existence of idle time and overtime in all of the runs indicates that some days have more orders than others. These days present demands on the vehicles which cannot be met, while other days find the vehicles with few or no deliveries to be made. If these peaks in orders could be anticipated several days in advance, planning over an extended period of time could smooth the work load over the extended periods.
This would involve extended lead time forecasts, and thus extensive program changes. The demands, actual and forecast, for several days, would have to be stored in the program, as the exact day of delivery to a given location would be variable within the planning period, thus the order quantity would be variable. A more intricate priority system would then be required, as stations lower in volume should be considered for delivery earlier.

4.4.3 Improved Operating Policy.

Sunday operation of the terminal should be considered, however all of the ramifications of the addition of an extra work day are not known at this time. The present simulated policy is the policy used by the petroleum company supplying the sales data for the simulation at one of their terminals.

In addition to the parameters which can now be varied, station tank sizes should be examined, not only with regard to demand for each product, but with regard to the ratio of demand at a given location. Further, this ratio may change due to different growth rates for different products. This would allow closer synchronization of the regular and premium orders. The lack of costs of altering the tank sizes may hinder a study of this type.

With varying ratios of regular to premium sales at the different stations, the fixed ratios of compartments is not an efficient policy, nor really an accurate simulation of realistic operating procedure. Three to four compartments are more common, allowing the ratio of regular to premium gasoline shipped on a given route to be varied.
The anticipated problems in multi-station routing would have to be solved, those involved in the allocation of compartments to products.

The routing algorithm could be improved or replaced in the simulation, although the best policy appears to be that of avoiding any multi-station routing if possible. Rather than consider multi-station routes, the reorder points could be set to permit full compartment sizes of both products to be delivered, with consideration given to the variable demand rates of the two products. Alternate drop points could be established to absorb excess loads, based on the order frequency of the alternative drop site as well as its proximity to the primary station.

4.4.4 Programming Improvements.

It is not recommended that the time increments of the simulation be decreased. This may permit more accurate modeling of stockouts and the timing of expedited orders, however the run time would be greatly increased. At present, 18 months can be simulated in four minutes; simulation on an hourly basis rather than a daily basis would not increase time linearly as there would be more detailed events and more intricate gathering of statistics. In decreasing run time, it may be possible to improve part of the coding. H level Fortran is not recommended as a means of increasing the execution speed of the simulation. Difficulties experienced in attempting to run this program in H level indicate that the compiled code does not give consistent results while the G level compiler presents no difficulties.
4.5 Conclusions

The general indications of these simulation experiments are that vehicle operating costs far outweigh the inventory carrying costs. Without sufficient costs to attach to lost sales and expedited orders, it is difficult to consider these indicators in relation to the given costs. Any alternative which yields better vehicle utilization is more acceptable than an alternative with poorer utilization. Single station routes yield better vehicle utilization over time, if the vehicle delivers a capacity load, as the frequency of delivery is decreased. The subsequent increase in inventories introduces negligible increases in carrying costs. The main problems preventing full capacity vehicle loads in the cases run are lack of variable compartment sizes and failure to examine variable reorder levels which would more nearly synchronize the ordering of both products at a given location.
INITIAL CONDITIONS

STARTING INVENTORY

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<thead>
<tr>
<th>STATION</th>
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<th>PREMIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
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TABLE 4.1
### INITIAL CONDITIONS

#### STARTING INVENTORY

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**TABLE 4.2**
### CORRESPONDENCE OF REPORT PERIOD TO DATE

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</thead>
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<tr>
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<td>3</td>
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<td>4</td>
<td>APRIL 16</td>
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<tr>
<td>5</td>
<td>MAY 14</td>
</tr>
<tr>
<td>6</td>
<td>JUNE 11</td>
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<td>7</td>
<td>JULY 9</td>
</tr>
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<td>8</td>
<td>AUG. 6</td>
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<td>OCT. 1</td>
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<td>26</td>
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**TABLE 4.3**
RESULTS OF SIMULATION

PREMIUM/REGULAR RATIO 2500/5500

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<tr>
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<th>DELIVERY FACTOR</th>
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<td></td>
<td>.7</td>
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<tr>
<td>TOTAL NUMBER OF TRIPS</td>
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</tr>
<tr>
<td>AVERAGE VEHICLE LOAD (GALLONS)</td>
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<td>NUMBER OF TRIPS WITH EXCESS LOAD</td>
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<td>TOTAL GALLONS EXCESS LOAD</td>
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<tr>
<td>TOTAL HOURS OVERTIME</td>
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<td>TOTAL HOURS IDLE TIME</td>
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<td>TOTAL VEHICLE RELATED COST</td>
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<td>AVERAGE DAILY DEMAND (GALLONS)</td>
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<td>PREMIUM</td>
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<td>TOTAL NUMBER OF DELIVERIES</td>
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<td>AVERAGE DELIVERY SIZE (GALLONS)</td>
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<td>NUMBER OF EXPEDITED ORDERS</td>
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<td>NUMBER OF DEFERRED ORDERS</td>
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<td>GALLONS LOST SALES</td>
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<td>AVERAGE COST PER GALLON SOLD</td>
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**Table 4.4**
### RESULTS OF SIMULATION

**PREMIUM/REGULAR RATIO 3000/5000**

#### DELIVERY FACTOR

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<th>.9</th>
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<td></td>
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<tr>
<td>Total Number of Trips</td>
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<td>96</td>
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**TABLE 4.5**
RESULTS OF SIMULATION

PREMIUM/REGULAR RATIO 3500/4500

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TABLE 4.6
TWELVE MONTH AVERAGES OF STATISTICS NON-COMPARTMENTALIZED VEHICLES

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TABLE 4.7
AVERAGE DAILY DEMAND FOR REGULAR GASOLINE
VS
SIMULATED TIME
SEED VALUE = 71747

REPORT PERIOD
FIGURE 4.1
AVERAGE DAILY DEMAND FOR REGULAR GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 10001

REPORT PERIOD
FIGURE 4.2
AVERAGE DAILY DEMAND FOR PREMIUM GASOLINE

VS.

SIMULATED TIME

SEED VALUE = 71747

Figure 4.3
AVERAGE DAILY DEMAND FOR PREMIUM GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 10001

REPORT PERIOD
FIGURE 4.4
AVERAGE INVENTORY OF REGULAR GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 71747

FIGURE 4.5
AVERAGE INVENTORY OF REGULAR GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 10001

REPORT PERIOD
FIGURE 4.6
AVERAGE INVENTORY OF PREMIUM GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 71747

REPORT PERIOD

FIGURE 4.7
AVERAGE INVENTORY OF PREMIUM GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 10001
TOTAL COST VS. SIMULATED TIME
SEED VALUE = 71747

FIGURE 4.9
AVERAGE LOAD PER TRIP VS.
DELIVERY FACTOR
FULL LOAD ~ 8000 GALLONS

GALLONS PER TRIP

DELIVERY FACTOR

FIGURE 4.11
AVERAGE REGULAR DELIVERY SIZE
VS.
DELIVERY FACTOR

GALLONS PER DELIVERY

3000/5000

3500/4500

2500/5500

DELIVERY FACTOR

FIGURE 4.13
AVERAGE PREMIUM DELIVERY SIZE
VS.
DELIVERY FACTOR

GALLONS PER DELIVERY

DELIVERY FACTOR

FIGURE 4.14
FIGURE 4.15
REFERENCES


Appendix A
Correlation Program
C001  DOUBLE PRECISION S(2,2), AM(2), X(750,2)
C002  KREAD=5
C003  NWRITE=6
C004  READ(IREAD, NG01) KPRCB
C005  9CC FORMAT(11)
C006  WRITE(IWRITE,930)
C007  930 FORMAT('EQUATION BETWEEN REGULAR AND PREMIUM GASOLINE SLOPS'}
Stratification Program
C001 COMMON PLT(15CC)
C002 AREAL=1
C003 NFIT=3
C004 "READINREAD,SCC01 NDS
C005 DO 10 J=1,NDS
C006 CU 10 I=1,2
C007 READ(NREAD,90CC) NO, NTYP, NSTAT
C008 90CC FORMAT(3I5)
C009 READ(NREAD,9010) (PLT(AD*K),K=1,NAD)
C010 901C FORMAT(15FS,C,5X)
C011 CALL STRAT(AD,NREAD,NFIT,NTYP,NSTAT)
C012 CALL PLOT(PLT,NC,1,NO,C)
C013 LC CONTINUE
C014 STOP
C015 END
C059  CG 70  J=3,14  KFS00750
C060  FRC5=FI(5)-1.1/FI(5)  KFS00416
C061  SS(I1)=SS(I1)+FRC5*PLT(ND+J)-AM(I1)*(PLT(ND+J)-AP(I1))  KFS00466
C062  AM(I1)=AM(I1)+FRC5*PLT(ND+J)/FI(5)  KFS00476
C063  7C  FI(5)=FI(5)+1.  KFS00486
C064  IS=200*IND  KFS00496
C065  IE=370+IND  KFS00506
C066  EO  80  J=15,16  KFS00516
C067  FRC6=FI(4)-1.1/FI(4)  KFS00526
C068  SS(I1)=SS(I1)+FRC6*PLT(ND+J)-AM(I1)*(PLT(ND+J)-AP(I1))  KFS00536
C069  AP(I1)=AM(I1)+FRC6*PLT(ND+J)/FI(4)  KFS00546
C070  8C  FI(4)=FI(4)+1.  KFS00556
C071  10C  CONTINUE  KFS00566
C072  FI(I2)=FI(I2)  KFS00576
C073  FI(I1)=FI(I1)  KFS00586
C074  FI(I9)=FI(I9)  KFS00596
C075  FI(I8)=FI(I8)  KFS00606
C076  FI(I7)=FI(I7)  KFS00616
C077  FI(I6)=FI(I6)  KFS00626
C078  FI(I5)=FI(I5)  KFS00636
C079  FI(I4)=FI(I4)  KFS00646
C080  FI(I3)=FI(I3)  KFS00656
C081  FI(I2)=FI(I2)  KFS00666
C082  AP(I2)=PLT(ND+J)  KFS00676
C083  FI(I1)=2.  KFS00686
C084  SS(I2)=0.0  KFS00696
C085  EO  300  J=4,371  KFS00656
C086  FRC72=(FI(I2)-1.1)/FI(I2)  KFS00666
C087  SS(I1)=SS(I1)+FRC72*PLT(ND+J)-AM(I1)*(PLT(ND+J)-AM(I1))  KFS00676
C088  AM(I1)=AM(I1)+FRC72*PLT(ND+J)/FI(I2)  KFS00686
C089  3CC  FI(I2)=FI(I2)+1.  KFS00696
C090  AM(I3)=PLT(ND+372)  KFS00706
C091  FI(I1)=3.0  KFS00716
C092  SS(I1)=0.0  KFS00726
C093  EO  325  J=373,735  KFS00736
C094  FRC73=(FI(I3)-1.1)/FI(I3)  KFS00746
C095  SS(I1)=SS(I1)+FRC73*PLT(ND+J)-AM(I1)*(PLT(ND+J)-AM(I1))  KFS00756
C096  AM(I1)=AM(I1)+FRC73*PLT(ND+J)/FI(I3)  KFS00766
C097  32S  FI(I3)=FI(I3)+1.  KFS00776
C098  EO  150  J=1,13  KFS00786
C099  SS(IJ)=(SS(IJ)/FI(IJ)-1.1)**S  KFS00796
C100  15C  CONTINUE  KFS00806
C101  WRITE(NRIT,600)  KFS00816
C102  5CC  FORMAT(1H1,7X),*ANALYSIS OF DATA BY STRATIFICATION*,///  KFS00826
C103  IF (NTYP.EQ.2) GO TO 6CC  KFS00836
C104  WRITE(NRIT,550) NSTAT  KFS00846
C105  55C  FORMAT(1X,150R5.0,1X,\ 12REGULAR GRADE GASOLINE - STATION 1,13,///  KFS00856
C106  GO TO 650  KFS00866
C107  6CC  WRITE(NRIT,625) NSTAT  KFS00876
C108  62S  FORMAT(1X,150R5.0,1X,\ 12PREMIUM GRADE GASOLINE - STATION 1,13,///  KFS00886
C109  65C  CONTINUE  KFS00896
C110  WRITE(NRIT,627)  KFS00906
C111  627  FORMAT(99X,CAY TO CAY,///  KFS00916
C112  WRITE(NRIT,675)  KFS00926
C113  67S  FORMAT(1X,150R5.0,1X,\ 12MUN.,11X,'TUE',11X,'WED',11X,'THU',11X,'FRI',11X,'SAT',11X,'Sun',///  KFS00936
C114  '11X,'Sun')  KFS00946
C115  72S  FORMAT(1X,150R5.0,1X,\ 12MEAN *,11X,'F9.2',11X,'F9.2',11X,'F9.2',11X,'F9.2',11X,'F9.2',///  KFS00956
15.2,5X*F9.2)
WRITE(700), (SD(J), J=1,17)
C118
775 FORMAT(*' WEEKENDS - WEEKDAYS',/)
WRITE(775)
C119
775 FORMAT(*' WEEKENDS',12X,'WEEKDAYS',/)
WRITE(775)
C120
825 FORMAT(*' MEAN ',3SX,F9.2,11X,F9.2)
WRITE(775)
C121
800 FORMAT(*' STD. DEVIAT. ',3SX,F9.2,11X,F9.2)
WRITE(775)
C122
85C FORMAT(*' SUMMER, F L I R T E R, FALL, SPRING',/)
WRITE(85C)
C123
875 FORMAT(*'SPRING',/)
WRITE(875)
C124
925 FORMAT(*' MEAN ',14X,F9.2,7X,F9.2)
WRITE(925)
C125
925 FORMAT(*' SD. DEVIAT. ',14X,F9.2,7X,F9.2)
WRITE(925)
C126
95C FORMAT(*' 1947 - 1968 ',/)
WRITE(95C)
C127
975 FORMAT(*' 1968 ',/)
WRITE(975)
C128
1025 FORMAT(*' MEAN ',14X,F9.2,11X,F9.2)
WRITE(1025)
C129
100G FORMAT(*' STD. DEVIAT. ',14X,F9.2,11X,F9.2)
WRITE(100G)
C130
105C FORMAT(*' P L E T I O * D A T A ',/)
WRITE(105C)
C131
C132
C133
C134
C135
C136
C137
C138
C139
C140
C141
C142
C143
C144
C145
RETURN
SUBROUTINE PLOT(A,N,M,PL,N5)

DIMENSION OUT(I1),YPR(I1),ANG(I1),A(I1)

2 FORMAT(1H1,F6.5,E10.1)
4 FORMAT(10H **C136/89)
5 FORMAT(10H)
7 FORMAT(1H1,E10.1)
8 FORMAT(1HO,9X,11F10.4/)

IF(N116,16,10)

SORT BASE VARIABLE IN ASCENDING ORDER

10 DO 13 I=1,N
11 DO 13 J=1,N
12 I(J)=I(J)+14,11
13 CONTINUE

F=A(I)

12 ALL=F

14,15 CONTINUE

TEST NULL

16 IF(INULL,20,18,20
18 ALL=50
20,22 CONTINUE

DEVELOP BLANKS AND EIGHTS FOR PRINTING

10 REWIND
41 WRITE(10,4)
10 REWIND
5 BLANK,ANG(I1),I=1,91
10 REWIND

FIND SCALE FOR BASE VARIABLE

XSCALE=(A(N)-A(I1))/(FLOAT(NULL-11))

FIND SCALE FOR CROSS VARIABLES

P1=N+1
P2=N+1

10 YMIN=A(P1)
10 VMX=YMM
10 X2=X2

40 J=H1,P2

C
C017    IF(A(J)-YP1)(I,J)=20,20,26
C030    26 IF(A(J)-YP1)(I,J)=40,40,30
C039    26 YMIN=A(J)
C040    CO TC 40
C041    3C YMAY=A(J)
C042    4C CONTINUE
C043    YSCAL=(YMAY-YMIN)/100.
C044    FINBASE VARIABLE PRINT POSITION
C045    X0=A(I)
C046    L=E
C047    M=Y-1
C048    45 F=I-1
C049    XPR=X0+F*XSCAL
C050    FIND CROSS VARIABLES
C051    S1 C0 55 I0=I,101
C052    55 CUT1(I)=SLA(1)
C053    57 CO 60 J=1,FY
C054    LL=L+J*#N
C055    JP=(I+LL)-YMIN)/YSCAL+1.0
C056    CONTINUE
C057    PRINT LINE AND CLEAF, OR SKIP
C058    WRITE(1,32)XPR,(CUT(I),I2=I,101)
C059    32 L=E+1
C060    RC I=I+1
C061    WRITE(1,86)XPR=AIN
C062    CC TC 51
C063    PRINT CROSS VARIABLES NUMBERS
C064    WRITE(1,43)
C065    43 YPR(I)=YMIN
C066    40 G YPR(I)=YPR(I)+YSCAL*10.0
C067    WRITE(1,81)YPR(I),I2=I,111
C068    RETURN
C070    END
Time Series Analysis Programs
The following is a multiple regression routine written by the author and used in conjunction with the spectral analysis routines. The required input variables are:

- **NM** - Number of variables
- **N** - Number of data points.
- **NPLT** - Number of plot points.
- **NLAG** - Number of lags.
- **IW** - Indicator of which spectral window is used.
  - 1 for Parzen.
  - 0 for Tukey-Hanning.
- **NSTAT** - Station number.
- **NTYP** - 1 if data is from regular gasoline.
  - 2 if data is from premium gasoline.
- **DW** - Plotting resolution.
- **X** - Vector of data points.
C

DIMENSION S(12,12), AM(12), SS(12,12), A(750), MM(12), LL(12), BL12KFS00000
1), R(12), SST(12,12), RESID(750)
COMMON X(750,12)
PI=3.1415927
REAL(1.200) NM,N,A,PLT,PLA,4L4,IN,NSTAT,HTYP,DW
200 FORMAT(15,F5.3)
1 IF (HTYP.EQ.1) GO TO 1000
WRITE (3,1010) NSTAT
1010 FORMAT(1X,'REGULAR GRADE GASOLINE - STATION ',I3,///)
GO TO 1030
1000 WRITE(3,1020) NSTAT
1020 FORMAT(1X,'PREMIUM GRADE GASOLINE - STATION ',I3,///)
1030 CONTINUE
WRITE(3,210) NM,N
210 FORMAT('NUMBER OF VARIABLES = ',12,NUMBER OF DATA POINTS)
1 ,N)
READ(1,1521)(X(I,1),I=1,N)
152 FORMAT(15F5.0,5X)
C
WRITE(3,230)
C
230 FORMAT(1X,'ECHO CHECK OF INPUT DATA '///)
C
WRITE(3,240)(X(I,1),I=1,N)
C
240 FORMAT(1X,'ECHO CHECK OF INPUT DATA '///)
C
TRANSFORMATIONS CN INDEPENDENT VARIABLES

C
CALL GAIX(N)
C
DO 190 I=1,N
F=1
FRC=3.01/FI
IF (I .EQ. 1) GO TO 153
GO TO 155
153 DO 154 J=1,NM
AM(J,J)=X(I,J)
154 CONTINUE
GO TO 140
155 DO 151 J=1,NM
AM(J,J)=X(I,J)+FRC*(X(I,J)-AM(J,J)+X(I,J)-AM(J,J))
151 CONTINUE
DO 156 K=1,NM
AM(J,J)=FRC*AM(J,J)+X(I,J)/F
156 CONTINUE
DO 190 I=1,NM
WRITE(3,250)
250 FORMAT(1X,'MEANS OF INPUT VARIABLES '///)
DO 260 I=1,NM
WRITE(3,270) I,AM(I)
260 CONTINUE
C
XX MATRICES
WRITE(3,280)
C
XPRIME X MATRIX '///
DO 157 J=1,NM
WRITE(3,158) (S(J,K),K=1,M)
158 FORMAT(1M8,8F15.6)
C
157 CONTINUE
200 NORMALIZATION
WRITE(3,200)
DO 160 J=1,M
DO 160 K=1,M
160 SSI(J,K)=SSI(J,K)/1.E0*(S(I,J)*S(K,K))**0.5
161 WRITE(3,161) (SSI(J,K),K=1,M)
DO 166 J=1,M
DO 166 K=1,M
166 LJ=1-J+1/M
LI=1-(J-1)*M
600 SSI(LJ,LI)=A(11)
WRITE(3,610)
610 FORMAT(///, * CORRELATION MATRIX INVERSE ,///)
DO 620 I=1,N
620 WRITE(3,630) (SSI(I,J),J=1,N)
DO 630 I=1,J
630 WRITE(3,310) 0
630 WRITE(3,300) 0
310 FORMAT(* DETERMINANT = *,E14.6)
WRITE(3,300)
300 FORMAT(///, * X PRIME Y MATRIX ,///)
DO 164 J=1,M
B(J)=SSI(J,N)/(S(J,J)*S(N,N))**C.5
164 WRITE(3,158) B(J)
LL=1
MSA=0
MSB=0
CALL MPRED(A,B,R,P,H,M,MSA,MSB,LL)
C C CALCULATE SUM OF SQUARES FROM REGRESSION
C CALL MPRED(R,B,SSQ,R,*,O,0,0,1)
WRITE(3,305)
105 FORMAT(* BETAS FROM CENTERED DATA ,*/)
DO 170 J=1,M
170 WRITE(3,159) J, R(J)
159 FORMAT(* B(J) = *,F15.6)
XL=0.0
DO 175 I=1,J
175 XL=XL+R(I)*X(I)
175 XL=XL*X(J)
WRITE(3,303) XL
830 FORMAT(* LENGTH OF BETA VECTOR = *,F15.6)
C CONVERT BETA VECTOR
DO 180 I=1,M
180 XL=XL+R(I)*X(I)
180 XL=XL*X(I)
DO 197 I=1,J
197 XL=XL+R(JI)*X(J)
197 XL=XL*X(I)
340 FORMAT(* ESTIMATES OF BETAS INCLUDING INTERCEPT TERM ,/*)
WRITE(3,350) R(J)
350 FORMAT(* B(J) = *,F15.6)
DO 195 I=1,J
195 XL=XL+R(I)*X(I)
195 XL=XL*X(I)
195 WRITE(3,360) IDX,R10X)
360 FORMAT(1X,3,D10)
C
C ANALYSIS OF VARIANCE
C
WRITE(3,700)
700 FORMAT(/' 4 ANOVA', 1X, 'ANALYSIS OF VARIANCE TABLE */)
WRITE(3,705)
705 FORMAT('1X, 'IN TERMS OF CORRELATIONS */')
WRITE(3,710)
710 FORMAT('1X, 'SOURCE ',15X, 'SUM OF SQUARES ',15X, 'DEGREES OF FREEDOM')
715 FORMAT(1X, 'SUM', 15X, 'MEAN SQUARE')
NDF3=NM-1
NDF2=NM-2
NDF1=N-1
SSAR=SM-SUM
N=n-1
TOTAL=S
M=1
G=1
NN=1
R=SEC
WRITE(3,720) SSM,NGF3,1
720 FORMAT(3X, 'SS',5X, 'NGF', 3X, '1')
SSAR=SUM/NGF3
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,730) SSM,NGF2,2
730 FORMAT(3X, 'SS',5X, 'NGF', 2X, '2')
SSAR=SUM/NGF2
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,740) SSM,NGF1,3
740 FORMAT(3X, 'SS',5X, 'NGF', 3X, '3')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,750) SSM,NGF1,4
750 FORMAT(3X, 'SS',5X, 'NGF', 4X, '4')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,760) SSM,NGF1,5
760 FORMAT(3X, 'SS',5X, 'NGF', 5X, '5')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,770) SSM,NGF1,6
770 FORMAT(3X, 'SS',5X, 'NGF', 6X, '6')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,780) SSM,NGF1,7
780 FORMAT(3X, 'SS',5X, 'NGF', 7X, '7')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,8
790 FORMAT(3X, 'SS',5X, 'NGF', 8X, '8')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,9
800 FORMAT(3X, 'SS',5X, 'NGF', 9X, '9')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,10
810 FORMAT(3X, 'SS',5X, 'NGF', 10X, '10')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,11
820 FORMAT(3X, 'SS',5X, 'NGF', 11X, '11')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,12
830 FORMAT(3X, 'SS',5X, 'NGF', 12X, '12')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,13
840 FORMAT(3X, 'SS',5X, 'NGF', 13X, '13')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,14
850 FORMAT(3X, 'SS',5X, 'NGF', 14X, '14')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,15
860 FORMAT(3X, 'SS',5X, 'NGF', 15X, '15')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,16
870 FORMAT(3X, 'SS',5X, 'NGF', 16X, '16')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,17
880 FORMAT(3X, 'SS',5X, 'NGF', 17X, '17')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,18
890 FORMAT(3X, 'SS',5X, 'NGF', 18X, '18')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,19
900 FORMAT(3X, 'SS',5X, 'NGF', 19X, '19')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,20
910 FORMAT(3X, 'SS',5X, 'NGF', 20X, '20')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,21
920 FORMAT(3X, 'SS',5X, 'NGF', 21X, '21')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,22
930 FORMAT(3X, 'SS',5X, 'NGF', 22X, '22')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,23
940 FORMAT(3X, 'SS',5X, 'NGF', 23X, '23')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,24
950 FORMAT(3X, 'SS',5X, 'NGF', 24X, '24')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,25
960 FORMAT(3X, 'SS',5X, 'NGF', 25X, '25')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,26
970 FORMAT(3X, 'SS',5X, 'NGF', 26X, '26')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,27
980 FORMAT(3X, 'SS',5X, 'NGF', 27X, '27')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,28
990 FORMAT(3X, 'SS',5X, 'NGF', 28X, '28')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,29
1000 FORMAT(3X, 'SS',5X, 'NGF', 29X, '29')
SSAR=SUM/NGF1
SUM=SUM/NDF1
SUM=SUM/NDF2
R2=SEC
WRITE(3,790) SSM,NGF1,30

LEAKERS = 1,F15,6)
165 CONTINUE
   CALL SPLITN,RES(1,1,DW)
   CALL PARZNI(RESID,1,NPLT,NLAG,IN,DW)
   STOP
END
SUBROUTINE DATKIN

COMMON X(1750,12)
PI=3.1415927
DO 10 I=1,N
FI=1
X(I,1)=FI
X(I,2)=COS(2.*PI*FI/7.)
X(I,3)=SIN(2.*PI*FI/7.)
X(I,4)=COS(2.*PI*FI/3.5)
X(I,5)=SIN(2.*PI*FI/3.5)
X(I,6)=COS(2.*PI*FI/182.5)
X(I,7)=SIN(2.*PI*FI/182.5)
X(I,8)=COS(2.*PI*FI/365.)
X(I,9)=SIN(2.*PI*FI/365.)
X(I,10)=COS(4.*PI*FI/73.)
X(I,11)=SIN(4.*PI*FI/73.)
10 CONTINUE
RETURN
END
The following routine is the stepwise regression routine written by IBM and modified by the KSU Computing Center. It is further modified for use with the spectral analysis routines. The input variables are explained:

- **NPROBS** - Number of problems.
- **NQ** - Number of Plot points.
- **MNQ** - Number of lags.
- **IW** - Indicator of which spectral window is used.
  - 1 for Parzen.
  - 0 for Tukey-Hanning.
- **DW** - Plotting resolution.
- **AID** - Vector for alphanumeric identification.
- **NVIN** - Number of variables to be read in.
- **NVAR** - Total number of variables.
- **NOBS** - Number of observations.
- **NSEL** - Number of selection cards.
- **FIN** - Limiting F value, with proper significance level and degrees of freedom, for entering variables.
- **FOUT** - Limiting F value, with proper significance level and degrees of freedom, for deleting variables.
- **IRES** - Set to 1 if spectral analysis is to be performed, 0 otherwise.
- **NFC** - Number of format cards.
NAME - Variable names vector.

FMT - Vector of formats.

DATA - Data vector.

NDEP - Subscript number of dependent variable.

NIIN - Number of variables to be considered for entry into the model.

ISAVE - Vector of the subscripts of the variables to be considered for entry into the model.
DIMENSIONED FOR 30. 30 VARIABLES INCLUDE 29 EXPLANATORY AND ONE DEPENDENT.
THE NUMBER OF OBSERVATIONS IS LIMITED TO 9999, AND MUST EXCEED THE NUMBER OF VARIABLES BY AT LEAST 2.
THE SPECIFIED INCOMING F LEVEL MUST NOT BE LESS THAN THE SPECIFIED OUTGOING F LEVEL.
THE VARIABLE FORMAT FOR THE DATA IS READ IN WITH THE CONTROL CARDS.
TRANSFORMATIONS ARE PERFORMED IN THE SUBROUTINE TRANS, AND MUST BE SPECIFIED ON THE DATA CARDS.
ADDED BY THE USER, SUBROUTINE TRANS MUST BE ADDED IF NO ADDED BY THE USER, SUBROUTINE TRANS MUST BE ADDED.
TRANSFORMATIONS ARE PERFORMED.
CARDS PRECEDING DATA MUST BE THESE, AND MUST OCCUR IN THIS ORDER.
NUMBER OF PROBLEMS
HEADING
PROBLEM PARAMETERS
VARIABLE NAME CODE
DATA FORMAT
DESCRIPTION OF THE FORMATS FOR THESE CARDS IS FOUND IN THE
PROGRAM WRITTEN.
THIS PROGRAM ASSUMES THAT VARIABLE NAMES WILL BE USED WITH THE DATA.
IF VARIABLE NAMES ARE NOT DESIRED, STATEMENT NO. 91 MUST BE CHANGED.
READ NAME, AND THE VARIOUS VARIABLE NAMES SHOULD BE INCLUDED IN THE DATA.
CARDS SPECIFYING THE DEPENDENT VARIABLE FOR EACH REGRESSION MUST
FOLLOW THE DATA.

PHASE 1. TRANSFORM ORIGINAL DATA, COMPUTE AND PRINT MEANS, STANDARD DEVIATIONS, AND SIMPLE CORRELATION COEFFICIENTS.

IMPLICIT REAL*8(A-H,O-Z)

DIMENSIONS XBAR(31), SIGMA(30)
DIMENSION DATA(30), R(30), FMT(100), DAT(50)
DIMENSION X(30), SIGMA(30), A(1)
DIMENSION SIGMA(30), B(1)
DIMENSION ZRES(1)

EQUIVALENCES SIGMA(1),DATA(1)
1 FORMAT(20X)
2 FORMAT(2I3,1G12.4)
3 FORMAT(F12.4,F10.4,F10.4)
4 FORMAT(3X)
5 FORMAT(4X)
6 FORMAT(6X)
7 FORMAT(10X)
8 FORMAT(10X)
9 FORMAT(20X)
10 FORMAT(20X)
11 FORMAT(20X)
12 FORMAT(20X)
13 FORMAT(20X)
14 FORMAT(20X)
15 FORMAT(20X)
16 FORMAT(20X)
17 FORMAT(20X)
18 FORMAT(20X)
19 FORMAT(20X)
20 FORMAT(20X)
21 FORMAT(20X)
22 FORMAT(20X)
23 FORMAT(20X)
24 FORMAT(20X)
25 FORMAT(20X)
26 FORMAT(20X)
27 FORMAT(20X)
28 FORMAT(20X)
29 FORMAT(20X)
30 FORMAT(20X)
31 FORMAT(20X)
32 FORMAT(20X)
33 FORMAT(20X)
34 FORMAT(20X)
35 FORMAT(20X)
36 FORMAT(20X)
37 FORMAT(20X)
38 FORMAT(20X)
39 FORMAT(20X)
40 FORMAT(20X)
41 FORMAT(20X)
42 FORMAT(20X)
43 FORMAT(20X)
44 FORMAT(20X)
45 FORMAT(20X)
46 FORMAT(20X)
47 FORMAT(20X)
48 FORMAT(20X)
49 FORMAT(20X)
50 FORMAT(20X)
51 FORMAT(20X)
52 FORMAT(20X)
53 FORMAT(20X)
54 FORMAT(20X)
55 FORMAT(20X)
56 FORMAT(20X)
57 FORMAT(20X)
58 FORMAT(20X)
59 FORMAT(20X)
60 FORMAT(20X)
61 FORMAT(20X)
62 FORMAT(20X)
63 FORMAT(20X)
64 FORMAT(20X)
65 FORMAT(20X)
66 FORMAT(*GOODNESS OF FIT,F(*,14,*,14,*,14,*)=,F(4,1))  
67 FORMAT(C OBS. ACTUAL ESTIMATE RESIDUAL)  
68 FORMAT(*,14,F(12,4))  
69 FORMAT(*SELECTION =,*,10X,DEPENDENT VARIABLE =,*,10X,14,*,14,*,14,*)  
70 FORMAT(INDEPENDENT VARIABLES *)  
71 FORMAT(*NUMBER OF SELECTIONS NOT SPECIFIED, JOB TERMINATED *)  
72 FORMAT(*DIABETES OF FREE DOM = 0, EITHER ADD MORE DATA OR DELETE *  
73 IS OR DELETE ONE OR MORE INDEPENDENT VARIABLES. * SAMPLE SIZE MUST *  
74 EXCEED NUMBER OF INDEPENDENT VARIABLES BY AT LEAST TWO *)  
75 FORMAT(*LEVEL FOR INCOMING VARIABLE IS LESS THAN F LEVEL FOR *  
76 OUTLIERING VARIABLE *)  
77 FORMAT(*)  
78 FORMAT(I0)  
79 FORMAT(*NORMAL END OF PKIGRAM *)  
80 FORMAT(*NVAR)  
101 ICOM=17991/2064  
102 READ (1,2) NPJOBS  
103 DD 1033 KA=1,1,NPJOBS  
104 REWIND 10  
105 C READ (2) NJOBS  
106 READ(1,3) NJ,MQ,IN  
107 READ(1,6) Iw  
108 READ(1,6) Iw(I,J),I=1,16  
109 C READ CONTROL CARD  
110 READ(1,2) NV1,1)].NV1,NC1,IN1,FIN,FOUT,1RES,1FC  
111 IF (FIN+FOUT) 1010,730,110  
112 170 IF(NPARA=1,1) GO TO 740  
113 READ(1,4) (INPAR(J,J),J=1,2,1=1,NPARA)  
114 C IF NPARA=1 GO TO 170  
115 IF(NFIC=1,1) GO TO 170  
116 NPARA=NPARA+1  
117 C INITIALIZE  
118 OJS=MQ  
119 DD 90 I=1,NVAR  
120 NVAR=1  
121 SIGMA(I)=0.0  
122 DD 90 J=1,NVAR  
123 C READ DATA: FORM SLMS VECTOR, S U M S O F Q U A R E S M AT R I X  
124 READ(1,2) P(M2,1),XBAR(1) 0.0  
125 DD 100 I=1,NVAR  
126 NVAR=1  
127 SIGMA(I)=0.0  
128 DD 90 J=1,NVAR  
129 ) C TRANSFORMATION OF RAW DATA  
130 CALL TRANS(M2,1),DATA(I)  
131 C WRITE DATA FILE  
132 C WRITE DATA FILE  
133 C COMPILE STANDARD DEVIATIONS SCOR ROUTE (NVAR-1)  
134 C WRITE DATA FILE  
135 C CONTINUE  
136 C COMPUTE STANDARD DEVIATIONS*SCOR ROUTE (NVAR-1)  
137 C COMPUTE CORRELATION MATRIX
DO 130 I=1,NVAR
DO 130 J=1,NVAR
RIJ(J,J)=RIJ(J,J)-XBAR(I)*XBAR(J)/OBS(/SIGMA(I)*SIGMA(J))
130 RRIJ(I,J)=RIJ(I,J)
C COMPUTE MEANS AND STANDARD DEVIATIONS
DO 140 I=1,NVAR
XBAR(I)=XBAR(I)/OBS
SIGMA(I)=SIGMA(I)/OBS-1.0)**.5
SSIGMA(I)=SIGMA(I)
140 XBAR(I)=XBAR(I)
C SKIP TO NEW PAGE, WRITE I.O., AVERAGES, STANDARD DEVIATIONS,
C AND SIMPLE CORRELATION MATRIX.
WRITE(3,65)RAID(I),I=1,181
IF(INHA.NE.1) GO TO 741
WRITE(3,5)
WRITE(3,61)NAME(J),J=1,2),I=1,NVAR
WRITE(3,51)
WRITE(3,52)I,XBAR(I),ICOM,I=1,NINDV,NVAR,XBAR(NVAR)
WRITE(3,53)I
WRITE(3,52)I,SIGMA(I),ICOM,I=1,NINDV,NVAR,SIGMA(NVAR)
WRITE(3,55)
CO 150 I=1,NINDV
C RAI(1),J=1,NVAR
150 WRITE(3,50111,J,RIJ(J,J),I=1,NVAR,RIJ(I,J),I=1,NVAR)
C PHASE 2. PERFORM STEPWISE CALCULATIONS AND PRINT RESULTS.
1031 DO 1032 N=1,NSEL
READ(1,84) NDEP, NIN, TSAVE(J),J=1,NIN
WRITE (3,99) NIN, NDEP, NIN
DO 151 I=1,NVAR
SIGMA(I)=SIGMA(I)
XBAR(I)=XBAR(I)
DO 152 J=1,NVAR
RIJ(I,J)=RIJ(I,J)
151 RIJ(J,J)=RIJ(J,J)
C INITIALIZE
DO 190 I=1,NVAR
SIGMA(I)=0.0
190 RIJ(I,J)=0.0
DO 190 N=1,DOF
OBS-1.0
C TRANSFORM SIGMA VECTOR FROM STANDARD DEVIATIONS TO SQUARE
C ROOTS OF SUMS OF SQUARES.
DO 310 I=1,NVAR
SIGMA(I)*SIGMA(I)=SIGMA(I)**2.0**.5
310 SIGMA(I)=SIGMA(I)*SIGMA(I)
C BEGIN STEP NUMBER NSTEP.
C NSTEP=NSTEP+1
200 NSTEP=NSTEP+1
C TSAVE(J)=TSAVE(J)*OBS**.5
IF (DF) 1000,1000,205
205 VMIN=0.0
VMAX=0.0
NIN=0
TSAVE(J)=TSAVE(J)*OBS**(1.0)**.5
C FIND MINIMUM VARIANCE CONTRIBUTION OF VARIABLES IN REGRESSION
C EQUATION. FIND MAYCIPM VARIANCE CONTRIBUTION OF VARIABLES
C NOT IN REGRESSION EQUATION.
DO 300 I=1,NVAR
I=I SAVE(J)
IF (E. EQ. NDEP) GO TO 300
KFS01190
KFS01540
KFS01200
KFS01190
KFS01540
KFS01200
KFS01220
KFS01230
KFS01260
KFS01280
KFS01250
KFS01270
KFS01290
KFS01310
KFS01360
KFS01340
KFS01320
KFS01350
KFS01370
KFS01390
KFS01400
KFS01380
KFS01420
KFS01430
KFS01440
KFS01460
KFS01480
KFS01490
KFS01500
KFS01510
KFS01520
KFS01530
KFS01540
KFS01550
KFS01560
KFS01570
KFS01580
KFS01590
KFS01600
KFS01620
KFS01640
KFS01660
KFS01670
KFS01680
KFS01690
KFS01700
KFS01710
KFS01720
KFS01740
KFS01750
KFS01760
KFS01770
KFS01780
IF(RIJ(1,1)-0.01) FOO, 300, 210
210 VE=RIJ(1,NDEP)*RIJ(1,NDEP)*RIJ(1,NDEP)/RIJ(1,1)
IF(VI) 240, 300, 220
220 IF(VI-VMAX)=300, 300, 230
230 VMAX=VI
GO TO 300
240 NIN=NIN+1
GO TO 10
C COMPUTE REGRESSION COEFFICIENT AND ITS STANDARD DEVIATION.
BIN(VI)=RIJ(1,NDEP)*SIGMA(NDEP)/SIGMA(1)
SIGMA(NIN)=SIGMA(NDEP+1)*SIGMA(NDEP+1)/SIGMA(1)
IF(VI)=VI
GO TO 1000, 100, 100
250 IF(VI-VMAX)=300, 300, 260
260 VMIN=VI
GO TO 300
C CONTINUE
IF(NIN)=1000, 400, 400
C COMPUTE CONSTANT TERM.
400 BSUB0=0.01(NDEP)
GO 410 I=1,NIN
J=ID(1)
410 BSUB0=BSUB0+0.01*RIJ(1)
IF(VI)=VI
GO TO 1000, 100, 100
C OUTPUT FOR VARIABLE ALGDEC
421 IF(VI)=VI C' GO TO 420
WRITE(1,51) NSTEP, E, (NAMEK(I), I=1,2)
GO TO 620
420 WRITE(3,57) NSTEP, E
WRITE(3,58) SIGMAE
R=(1.0-RID[J,NDEP,NDEP])**2.5
WRITE(3,59) R
IDEN=CHS-DF-2.0
IF(0.0) F=0.0
IF(SIGMA(NDEP)**2.0) SIGMAE**2.0)/IDEN*1.0
WRITE(3,60) IDEN, SIGMAE
WRITE(3,61) E
WRITE(3,62)
DO 430 I=1,NIN
J=ID(1)
430 T=1.0/SIGMA(I)
430 T=1.0/SIGMA(I)
C COMPUTE F LEVEL FOR MINIMUM VARIANCE CONTRIBUTION VARIABLE
C IN REGRESSION EQUATION.
FLLEV=MIN(0.0, RID[I,J,NDEP])
EFFD=F*FLLEV*4.0, 460, 450
C INITIALIZE FUR REMOVAL OF VARIABLE K FROM EQUATION.
450 K=NIN
N=0
DF=DF+2.0
GO TO 800
C COMPUTE F LEVEL FOR MAXIMUM VARIANCE CONTRIBUTION VARIABLE
C IN EQUATION.
FLLEV=VMAX*(RID[I,J,NDEP,NDEP])=VMAX
460 IF(FLLEV-FIN)=460, 460, 470
C INITIALIZE FUR ENTRY OF VARIABLE K INTO EQUATION.
470 K=MAX
N=K
GO TO 500
C  OUTPUT FOR VARIABLE DELETED
480 WRITE(3,64)STEP,K
   GO TO 425
C  UPDATE MATRX
500 GO TO 510,12=1,NIINI1
   I=ISAVE(I)
   IF(1-KI510,540,51C
510 GO 530 J=1,NIINI1
   J=ISAVE(J)
   IF(J-KI520,530,52C
520 RIJI(J,J)=RIJI(J,J)-RIJ(J,1,K)*RIJ(K,J)/RIJ(K,K)
530 CONTINUE
540 CONTINUE
   DO 560 J=1,NIINI1
   J=ISAVE(J)
   IF(J-KI550,560,55C
550 RIJI(K,J)=RIJI(J,K)/RIJ(K,K)
560 CONTINUE
   DO 580 I=1,NIINI1
   I=ISAVE(I)
   IF(I-KI570,580,57C
570 RIJI(J,K)=RIJI(K,0)/RIJ(K,K)
580 CONTINUE
   RIJI(K,K)=RIJ(K,K)
   GO TO 200
600 IF(RESI<10.1032,610
C  PRINT RESIDUALS
610REWIND 10
   DO 620 K=1,NOBS
       READ(IO1)DATA(K),I=1,NOVAR
       EST=SU(HO
       DO 620 I=1,NIIN
       J=1(I)
620 EST=EST+DATA(I)*DATA(J)
   ZRESIKO=DATA(I)*DEPI-EST
630 CONTINUE
   REWIND 10
   NO=1
   CALL SPLUT(NOBS,ZRESO,NO,NW)
   CALL PARZNI(ZRESO,NGBS,NCS,NQS,NQW,1,NW)
1012 CONTINUE
1033 CONTINUE
   WRITE(3,85)
   GO TO 1020
1000 WRITE(3,82)
   GO TO 1020
1030 WRITE(3,80)
   GO TO 1020
1010 WRITE(3,83)
1020 STOP
   END
SUBROUTINE TRANSDATA, I

DIMENSION DATA(30)
DOUBLE PRECISION DATA, DSIN, DCOS, PI
PI = 3.1415927
JDX = (I-1)/735
F1 = 1 - 735*JDX
DO 5 J = 1, 732
5 DATA(J) = 0
DO 10 I = 0, 7
10 DATA(I) = 0
DATA(2) = F1
DATA(3) = DCOS(2.*PI/F1/182.5)
DATA(4) = DSIN(2.*PI/F1/182.5)
DATA(5) = DCOS(2.*PI/F1/365.1)
DATA(6) = DSIN(2.*PI/F1/365.1)
INDEX = I7
INDEX = INDEX/7
GO TO 80

C DAY 1 IS MONDAY

IF (INDEX .EQ. 1) GO TO 20
IF (INDEX .EQ. 2) GO TO 50
IF (INDEX .EQ. 3) GO TO 40
IF (INDEX .EQ. 4) GO TO 50
IF (INDEX .EQ. 5) GO TO 60
IF (INDEX .EQ. 6) GO TO 70
GO TO 80

20 DATA(7) = 1
GO TO 80
30 DATA(8) = 1
GO TO 80
40 DATA(9) = 1
GO TO 80
50 DATA(10) = 1
GO TO 80
60 DATA(11) = 1
GO TO 80
70 DATA(12) = 1
GO TO 80

80 CONTINUE
DATA(13) = F1/10000.
DATA(14) = DCOS(2.*PI/F1/91.25)
DATA(15) = DSIN(2.*PI/F1/91.25)
DATA(16) = DCOS(2.*PI/F1/45.625)
DATA(17) = DSIN(2.*PI/F1/45.625)
DATA(18) = DCOS(2.*PI/F1/30.46)
DATA(19) = DSIN(2.*PI/F1/30.46)
DATA(20) = DCOS(2.*PI/F1/60.83)
DATA(21) = DSIN(2.*PI/F1/60.83)
IF (INDEX .EQ. 1) GO TO 40
IF (INDEX .EQ. 2) GC TO 100
IF (INDEX .EQ. 3) GC TO 110
IF (INDEX .EQ. 4) GC TO 120
IF (INDEX .EQ. 5) GC TO 125
IF (INDEX .EQ. 6) GC TO 126
IF (INDEX .EQ. 7) GC TO 127
GO TO 130
90 DATA(22)=1.
   GO TO 130
100 DATA(23)=1.
   GO TO 130
110 DATA(24)=1.
   GO TO 130
120 DATA(25)=1.
   GO TO 130
125 DATA(26)=1.0
   GO TO 130
126 DATA(27)=1.0
   GO TO 130
127 DATA(28)=1.0
130 CONTINUE
   RETURN
   END
SUBROUTINE PARZNI(X,N,NG,M,IW,DW)

THIS PROCEDURE COMPUTES THE AUTO CORRELATION FUNCTION, RI, FOR
I=1,2,....,M+1. THE FUNCTION AT LAG M IS STORED AT I=M+1. THE
TIME SERIES ARE OF LENGTH N, AND IS STORED IN THE ARRAY Y,
BEGINNING AT LI. THE AUTO CORRELATION FUNCTION IS NORMALIZED
TO HAVE A VALUE 1 AT THE ORIGIN. THE NORMALIZING FACTOR IS DI.
THE FUNCTIONS ARE ADDED INTO THE ARRAY R1.

1 FORMAT(214)
2 FORMAT(4X,F5.0,4X,F5.0)
3 FORMAT(F12.5,12X,F12.5)
4 DIMENSION X(1)
5 REAL Y(JJ),Y(JJ),X(I)
6 DATA D1,D3/0.0,0.0,C/
7 PMO
8 DO 5 I=1,N
9 D1=DI+X(I)**2
10 5 CONTINUE
11 PM=PM+1
12 DO 7 KK=1,M
13 KKI=KK-1
14 NH=N+KK
15 NK=N+KK
16 SUMI=0.0
17 DO 6 JI=1,N
18 SUMI=SUMI+X(JI)*X(JI+KK)
19 6 CONTINUE
20 R1(KK)=SUMI/DI
21 7 CONTINUE
22 CALL SPLT(M,R1,Z,DW)
23 CALL PARZNI1(M,NG,M,IW,DW)
24 RETURN
25 END
SUBROUTINE PARIN2(R1, NR, KI, INPUT, W, D)

THIS PROCEDURE COMPUTES N+1 POINTS OF THE ESTIMATED SPECTRAL
DENSITY FUNCTION FROM R(1) WHICH IS THE AUTO CORRELATION FUNCTION
THE TRUNCATION POINT IS K, THE WEIGHTING KERNEL USED IS OMEGA.
THE SINES AND COSINES NEEDED ARE COMPUTED RECURSIVELY

DIMENSION RL(750)
REAL OMEGA(750),OMEGAW(750),R1(750),F1(750),FO(750)
PL=3.2,15927
PI=3.1415927
PIV=1/PI

1 FORMAT(4F10.5)
2 FORMAT(12I8)
F1=1.0
F2=R1(1)

IF(WM 32)30,33,32

32 ML=M/2
M2=M+1
DO 33 I=1,M
33 OMEGA(I)=1.0-6.0*(I-1)/M**2+6.0*(I-1)/M**3

34 OMEGA(I)=OMEGAW(I)*2+1.0/M**3
GO TO 31

30 DO 3 I=1,M
3 OMEGA(I)=1.0+COS(I*PI/M))

31 C=0
C1=COS(IW)
C3=C1
C2=SIN(IW)
D4=C2
D6=2.0+C1
PIW=OMEGAW(I)
K=M1
DO 4 I=2,K
A=OMEGA(I)
P1=P1+R1(I)*A
4 CONTINUE
F1(I)=P1*PIV

5 CONTINUE
F1(I+1)=D1*U21-U11+R1(I)*0.5*PIV
O1=(C1*C3)-(C2*D4)
D4=(D4*C1)+(C3*C2)
C3=D1
O6=2.0*O1
6 CONTINUE
CALL SPLT(NQ,F1,1,EW)
RETURN
END
SUBROUTINE SPLIT(X,N,NO,DW)

THIS ROUTINE IS USED TO MODIFY THE RESULTS FROM THE PARIEN SUBROUTINE PLTT.

DIMENSION X(100),CUT(100),YPH(111),ANG(9),PLT(1600),Y(100)

102 FORMAT(6X,'PLOT VALUES',1(BF14.5))

C
C INITIALIZE VALUES

PI=3.1415927
K=0
M=2
IF(NO.NE.3) GC TO 10
DO 106 I=1,N
IF(X(I))GT 100,100,95
99 X(I)=ALOG(X(I))
100 X(I)=10.0
106 CONTINUE

DO 8 I=1,N
PLT(I)=1*DW
PLT(I+N)=X(I)
8 CONTINUE

GO TO 20
10 DO 11 I=1,N
PLT(I)=I
PLT(I+N)=X(I)
11 CONTINUE

CALL PLTT(N,PLT,A,N,N,0)
WRITE(0,102) (X(I),I=1,N)
RETURN
END
SUBROUTINE PLOT(NC,N1,N2,N3,N4,N5,NS)
DIMENSION OUT(101),YPR(11),ANG(9),A11

1 FORMAT(1H1,60X,7H CHART #3,13,11)
2 FORMAT(1H ,Fi14.5H ,10i11)
3 FORMAT(1H )
4 FORMAT(1H **Q156789)
5 FORMAT (10A1)
6 FORMAT(1H ,10X,10H .
7 FORMAT(1H ,10X,10H .
8 FORMAT(1H0,4X,11F10.4/
9 FORMAT(1H ,10X,10A11
200 FORMAT (10X,* PLOT OF DATA*)
201 FORMAT (10X,* PLOT OF AUTO CORR. FUNCTION*)
202 FORMAT (10X,* PLOT OF SPECTRUM*)

******************************************************************************
NLL=NL

IF(NS)16,16,10

SORT BASE VARIABLE IN ASCENDING ORDER

10 DO 15 I=1,N
11 L=I-1
12 LL=J-N
13 IF(1E+11J.IJ..4,14,11)
14 CONTINUE
15 CONTINUE

TEST NLL

16 IF(NLL)20,18,20
18 NLL=50

PRINT TITLE

20 WRITE(3,11Nd
20 WRITE(3,11Nd
21 WRITE(3,201)
21 WRITE(3,201)
21 WRITE(3,201)
21 CONTINUE

DECLARE BLANKS AND DIGITS FOR PRINTING
REWO N4
WRITE(4,4)
REWO N4
READ(*,5)BLANK,(A(N),I=1,9)
REWO N4
C
C
FIND SCALE FOR BASE VARIABLE
XSCAL=(A(N)-A(N))/(1.0F0/7.71)
C
C
FIND SCALE FOR CROSS VARIABLES
M=1+1
YMIN=A(M)
YMAX=YMIN
W=1+1
DD 40 J=M+1
IF(A(J)-YMIN)128.2E,26
26 IF(A(J)-YMAX)140.48.30
28 YMIN=A(J)
GO TO 40
30 YMAX=A(J)
40 CONTINUE
YSCAL=(YMAX-YMIN)/10000
C
C
FIND BASE VARIABLE PRINT POSITION
XB=A(I)
L=1
PF=N-1
I=1
45 F=I-1
XPR=XB+F*YSCAL
C
C
IF(A(L)=XPR)51,51,70
C
C
FIND CROSS VARIABLES
C
51 DD 55 I=1,101
55 OUT1(I)=BLANK
57 DD 60 J=I,MY
LL=1+1
JP=1+(I-LL)/YMIN/YSCAL+1.0
OUT(JP)=ANG(J)
60 CONTINUE
C
C
PRINT LINE AND CLEAR, OR SKIP
C
WRITE(3,2)XPR,(OUT(I),I=1,101)
L=L+1
GO TO 80
70 WRITE(3,3)
80 I=I+1
IF(I-1)1145.84.86
84 XPR=A(N)
GO TO 51
C
C
PRINT CROSS VARIABLES NUMBERS
C
86 WRITE(3,7)
YPR(I)=YMIN
DD 90 KN=1,9
90 YPR(KN+1)=YPR(KN)+YSCAL*10.0
YPR(1)=YMAX
WRITE(3,8)(YPR(IR),IR=1,11)
RETURN
END
Simulation Programs
SIMULATION INPUT VARIABLES

The required input variables for both the compartmentalized and non-compartmentalized vehicles programs are the same, except for parameters defining the number of vehicle compartments and the size of the compartments. The first card is a control card containing the following variables in the specified format:

NSTAT - Number of stations, format I5.

NV - Number of vehicles, format I5.

NC - Maximum number of coefficients in the models, including the constant term and the standard error of estimate, format I5.

NT - Number of periods represented by terms in the model, format I5.

NM - Number of different models, format I5.

NSP - Number of station parameters read into the model, format I5.

NVP - Number of vehicle parameters read into the program, format I5.

ITIM - The time length of the simulation run, in days, format I5.

ICH - Switch for echo check, format I5.

0 - No echo check.

1 - Echo check.

IRPT - Number of days in a report period, format I5.

IX - Seed value, format 110.
NSFTS - Number of shifts in an operating day, format I5.

The following tow cards contain descriptive elements of the system:

CR - Cost of regular gasoline at the terminal, format F10.4.
CP - Cost of premium gasoline at the terminal, format F10.4.
CC - Carrying cost (yearly % of product cost at the station), F10.4.
CD - Driver's hourly wages, format F10.4.
CMT - Vehicle maintainence cost per mile of operation, F10.4.
COP - Vehicle operating cost per mile of operation, F10.4.
CLT - Cost of taxes, licensing, and insurance for an 8000 gallon capacity vehicle, per year, format F10.4.
RL - Vehicle loading rate, F10.4.
DF - Delivery factor, F10.4.
UF - Utilization factor, F10.4.
CTUN - Constant time associated with vehicle unloading, F10.4.
CTLD - Constant time associated with vehicle loading, F10.4.

There follows one card for each of the periods represented by terms in the models. Each card contains the number of days in one of the periods. These cards should be in the order of the periods' appearance in the models:

\[ P(J) \] - Number of days in the \( J^{th} \) periodic term, F10.4.

The next set of cards contains the model coefficients. Any single model may require several cards. Each different model must begin on a new card:

\[ COF(1,J) \] - The \( J^{th} \) coefficient of the \( i^{th} \) model, F10.4.

The next set of cards consists of 1 card for each station. Each card contains three pieces of data:
IT1(I) - Station site type code, I2.
    1 - Interstate.
    2 - Business.
    3 - Residential.
    4 - Shopping center.

ST2(I,1) - Regular level adjustment, F10.4.
ST2(I,2) - Premium level adjustment, F10.4.

The next set of cards define the input parameters for the stations, which are stored in the SMRM matrix. As with the model coefficients, any number of cards may be required to input all parameters for a given station. Each different set of station parameters must begin on a new card:

SMRM(I,J) - The \( J^{th} \) parameter for the \( I^{th} \) station, F8.2.

The next set of cards define the input parameters for the vehicles, which are stored in the VMRM matrix. More than one card may be used for each vehicle, if required, however each new set of parameters for a different vehicle must begin on a new card:

VMRM(I,J) - The \( J^{th} \) parameter for the \( I^{th} \) vehicle, F8.2.

The next set of cards provide for the input of the distance matrix. The lower triangular matrix of distances is read in. Each row of the matrix begins on a new card. Continuation cards for a given row may be used. The first column in each row represents the distance from the terminal to the \( I^{th} \) station:

DIS(I,J) - The distance from the \( J^{th} \) point to the \( I^{th} \) point, F4.1.

Similarly, the final set of cards inputs the travel times for each link in the network of the stations and the terminal:

TIM(I,J) - The time required to travel from the \( J^{th} \) point to the \( I^{th} \) point, F4.1.
THE MAIN PROGRAM READS IN ALL INITIAL VALUES OR PRESETS THEM FOR THE FIRST L
BEGINNING OF THE SIMULATION, AS WELL AS KEEPS TRACK OF TIME AND THE N
CURRENT EVENT.

COMMON SWRM(25,16), VMRM(10,16), X(10), YH(10), XXL(10), Y(10), YH(KF$00000
110), YY(10), COF(10,25), ITL(25), STZ(25,2), NSTAT, NV, NWRIT, NREK$00000
2AD, RL, RU, GF, UF, CTUN, CTDL, TUNT, NDF0G, NSFTS, SHTR, SHTP
COMMON/NWTR/TIM(25,25), DIS(25,25), SAV(25,25), CMI(25,25), UFILE(KF$00000
12,25), NHR(25)
DIMENSION P(20)

INITIALIZATION

NREAD=5
NWRIT=6
PI=3.1415927
DO 5 I=1,15
P(NP(I))=0.0
DO 5 J=1,15
5 SPWRM(I,1)=0.0
DO 10 J=1,15
10 CM1(I,1)=0.0
DO 15 I=1,15
15 VMRM(I,1)=0.0
TUNT=0.0
LRT=0
NDF0G=0
SHTR=0.0
SHTP=0.0

READ IN DATA

READ(NREAD,1000) NSTAT, NV, NC, NK, NM, NSP, NVP, ITIM, ICH, IRP
1000 FORMAT(10I5,10D15.15)
READ(NREAD,1005) CR, CP, CC, CD, CM, COF, CMI, RL, RU, GF, UF, CTDL
1005 FORMAT(10D15.15)
READ(NREAD,1006) F(J)
1006 FORMAT(1D15.15)
READ(NREAD,1007) J(J)
1007 FORMAT(1D15.15)
READ(NREAD,1008) X(J)
1008 FORMAT(1D15.15)
READ(NREAD,1009) Y(J)
1009 FORMAT(1D15.15)
READ(NREAD,1010) Z(J)
1010 FORMAT(1D15.15)
READ(NREAD,1011) W(J)
1011 FORMAT(1D15.15)
READ(NREAD,1012) V(J)
1012 FORMAT(1D15.15)
WRITE(*,1092)
1092 FORMAT(IX,* PERIOD,15X,*SINE,14X,*INITIAL,14X,*COSINE,14X,*LABELS,14X,*EXTENSION,14X,*)
1100 FORMAT(*,13X,*INCORRECT,10X,*SINE VALUE,11X,*INCORRECT,11X,*COSINE,11X,*)
25X,NEXT,11X,*)
DO 120 J=1,NT
120 WRITE(*,11101) P(J), X(J), KH(J), Y(J), YH(J)
1110 FORMAT(*,20X,*)
1 PREMIUM CONSTANT ,/18X,* NUMBER,2X,*TYPE,/*,
DO 130 J=1,NSTAT
130 WRITE(*,11201) J, ITIL(J), ST2(J,1), ST2(J,2)
1120 FORMAT(*,12X,*,12X,*,3X,F9.4,2X,F9.4)
NSP1=NSP-1
WRITE(*,11301) (J,J=(1,NSP1))
1130 FORMAT(*,36X,*STATION MASTER REFERENCE MATRIX ,/1,10X,*NUMBER,5X,F8.4,7X,/) ,
,10X,*INDEX,10X,*DICTIONARY MATRIX ,/>
1140 FORMAT(*,10X,*,10X,2X,F10.4,2X,F10.2)
WRITE(*,11501) (J,J=(1,8))
1150 FORMAT(*,39X,*VEHICLE MASTER REFERENCE MATRIX ,/1,10X,*NUMBER,5X,F8.4,7X,/) ,
,10X,*INDEX,10X,*DISTANCE MATRIX,*/,/1,10X,*INDEX,10X,*TIME MATRIX,*/,/1,10X,*INDEX,10X,*SATINGS MATRIX,*/,/1,10X,*INDEX,10X,*INDEX,10X,*INDEX,10X,*)
DO 170 J=1,NSTAT
170 WRITE(*,11901) (J,J=(1,J1))
1190 FORMAT(*,24X,*)
CONTINUE
RU=RU*60.0
KRL=KRL*60.0
RPTP=RPTP/60.0
CC=CC*RPTP
CLT=CLT*RPTP
C
C EVENT SCHEDULING AND MONITORING

C

I=1
100 IDX=I/IAPR
   IDX=I-IDX*IMPT
   CALL STOAY(I, NC, NT, VM, IC)
   IF (IDX .LE. 0) GO TO 210
   GO TO 220
210 CALL RPURT(I, CR, CF, CC, GD, CM, GD, CL, LR, IRPT)
220 IF (I .EQ. ITIF) GO TO 200
   I=I+1
   GO TO 100
200 CONTINUE
STOP
END
SUBROUTINE STAY(I, NC, NT, N, IX)

C THIS SUBROUTINE MAKES THE DAILY FORECASTS AND UPDATES THE PREDICTED
C AND ACTUAL INVENTORY STATUS FOR EACH STATION. THE PREDICTED AND ACTUAL
C STATUS ARE CHECKED AGAINST SAFETY LEVELS TO DETERMINE THE DAY'S
C DELIVERY FILE.
C
COMMON SMRM(25,18), VRM(10,16), X(10), XM(10), XX(10), Y(10), YH(10)
100, Y(10), COF(10,25), IT(25), ST(25), NT(25), SM(25), NT(25), N(25),
200, RL, R, RN, UF, UMT, C, C1, C2, C3, C4, NDEF, NT(25), SHTP, SHTR,
COMMON(115)(K(25), M(25), D(25), T(25), S(25), H(25), U(25), T(25),
250, V(25), C(25), SM(25), Y(25), YH(25), COF(25), IT(25), ST(25),
COMMON(140)(10,16), N(10), NT(10), N(10), NT(10), N(10), NT(10),
270, SM(10), XM(10), SM(10), XM(10), SM(10), XM(10), SM(10), XM(10),
COMMON(180)(10,16), N(10), NT(10), N(10), NT(10), N(10), NT(10),
DIMENSION VCM(30), TOT(10), RN(10), WEDM(25,4)
C
C 10 I=1, IX
C 20 IX=1-IX*7
C 30 P1=1.1415927
C
C IF (IX .EQ. 0) GC TO 8
C
C RESET VEHICLE DAILY MILEAGE TOTALS, UPDATE INVENTORY RECORDS
C
C 10 J=1, NV
C 20 J=1, NSTAT
C IF (NPRI(J) .LE. 0) GO TO 3
C NPRI(J)=0
C 30 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
C 40 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
C 50 GO TO 7
C 60 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
C 70 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
C GO TO 15
C
C 80 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
C 90 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
C 100 IF (SMRM(J,8) .GE. 0.0) GO TO 4
C 110 SHTR=SHTR-SHTR(J)
C 120 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
C 130 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
C 140 IF (SMRM(J,8) .GE. 0.0) GO TO 9
C 150 CONTINUE
C 160 GO TO 120
C
C SET UP ITERATIVE SIM - COS ROUTINE
C
C 15 J=1, NT
C 20 J=1, NT
C 30 YH(J)*=YH(J)*+YH(J)*X(J)
C 40 YH(J)*=YH(J)*+YH(J)*X(J)
C 50 YH(J)*=YH(J)*+YH(J)*X(J)
C 60 YH(J)*=YH(J)*+YH(J)*X(J)
C
C CREATE MULTIPLIER VECTOR
C
C 10 J=1, NT
C 20 VCM(1)=0.0
C 30 S1=1*1
C
IF (NPR(J) .EQ. 0) GO TO 60
IF ((SMMK(J,6)-SMMK(J,4)) .LE. 0.0) NPR(J)=2
IF ((SMMK(J,9)-SMMK(J,5)) .LE. 0.0) NPR(J)=2
IF (NPR(J) .LT. 0.0) GO TO 70
OPEN (L,J=SMMK(J,2)-SMMK(J,8))
OPEN (L,J=SMMK(J,3)-SMMK(J,9))
GO TO 70
60 OPEN (L,J=SMMK(J,2)-SMMK(J,6)+DRF)
OPEN (L,J=SMMK(J,3)-SMMK(J,7)+CF)
GO TO 70
C DETERMINE SUNDAY DEPANU FOR CREATION OF SATURDAY ORDER FILE.
C
55 DRA=DRF+R(N(1))
   DPA=DPF+R(N(2))
   IF (DRF .LE. 0.0) DRF=0.0
   IF (DPF .LE. 0.0) DPF=0.0
   IF (DRA .LE. 0.0) DRA=0.0
   IF (DPF .LE. 0.0) DPA=0.0
   WEDM(J,1)=DRF
   WEDM(J,2)=DPA
   WEDM(J,3)=DRA
   WEDM(J,4)=DPA
   SMMK(J,17)=SMMK(J,17)*WLEM(J,1)
   SMMK(J,18)=SMMK(J,18)*WLEM(J,2)
70 CONTINUE
IF (IDX .EQ. 0) GO TO 75
IF (IDX .NE. 0) GO TO 110
IDX=0
GO TO 15
75 DO 100 J=1,NSTAT
   IF (NPR(J) .LT. 0) GO TO 100
   IF ((SMMK(J,6)-WLEM(J,1)-SMMK(J,4)) .LE. 0.0) NPR(J)=1
   IF ((SMMK(J,7)-WLEM(J,2)-SMMK(J,5)) .LE. 0.0) NPR(J)=1
   IF (NPR(J) .LT. 0) GO TO 100
   IF ((SMMK(J,8)-WLEM(J,3)-SMMK(J,9)) .LE. 0.0) NPR(J)=2
   IF ((SMMK(J,9)-WLEM(J,4)-SMMK(J,5)) .LE. 0.0) NPR(J)=2
   IF (NPR(J) .LT. 0) GO TO 100
   OPEN (L,J=SMMK(J,2)-SMMK(J,8))
   OPEN (L,J=SMMK(J,3)-SMMK(J,9))
   SMMK(J,12)=SMMK(J,12)*WLEM(J,3)
   GO TO 100
90 OPEN (L,J=SMMK(J,2)-SMMK(J,6))
   OPEN (L,J=SMMK(J,3)-SMMK(J,7))
100 CONTINUE
110 CALL ROUT(I)
120 RETURN
END
SUBROUTINE ROUT1
COMMON SPRM(25,101), VMRR(10,161), XI(101), XH(101), XX(101), YI(101), YM(100), NPKS(3600)
101, YH(101), GOP(10,25), I11(25), SI(25,2), NSTAT, V1, VMRR1, NREKSF(3600)
2AO, RL, RU, D2, UF, CTU, CTUO, TUNIT, NDEFO, NSFTS, SNRT, SHIP
12, 25, WPR(25), DIS(25), I01D(25), IROUT(125,4), TLOAD(125,4), MTIME(KSF,512,60)
151, LV(125), XFILE(125), RTOI(125), DVT(10)

C
SFIN=NSFTS
DO 2 J=1,5
DO 2 K=1,NSTAT
XFILE(J,K)=0.0
2 TLOAD(J,K)=0.0
C
DO 3 J=1,NSTAT
3 RTOI(J)=2.0*D1(12)
DO 4 J=1,NV
4 OVT(J)=0.0
C
C INITIALIZE SAVINGS MATRIX
C
DO 5 J=1,NSTAT
DO 5 K=1,NSTAT
5 SAV(J,K)=SSAV(J,K)
C
C ESTABLISH INDIRECT INDEX
C
JDX=0
DO 20 K=1,NSTAT
IF (NMK1) .NE. 0 GO TO 10
GO TO 20
10 JDX=JDX+1
20 CONTINUE
IF (JDX .EQ. 0) GO TO 105
DO 30 J=1,NSTAT
30 JDX=JDX+1
30 IROUT(J)=0
C
C THIS SECTION MAKES THE INITIAL ALLOCATION OF VEHICLES TO SINGLE STATION ROUTES
C
K=0
50 K=K+1
DO 40 J=1,JDX
JN(JDX)=JN(J+1)
40 LOAD=0
IF (IFILE(JN(J),JNIO) .EQ. (UP*VMRR(K,51)) AND. OFILE(JN(J),JNIO) .EQ. VMRR(K,51)) GO TO 40
40 IF (IFILE(JN(J),JNIO) .EQ. UP*VMRR(K,51)) GO TO 40
40 IF (OFILE(JN(J),JNIO) .EQ. VMRR(K,51)) GO TO 40
IF (IFILE(JN(J),JNIO) .EQ. VMRR(K,51)) GO TO 70
70 NLOAD(1,JN(J),JNIO)=IFILE(1,JN(J),JNIO)
XFILE(JN(J),JNIO)=OFILE(1,JN(J),JNIO)
OFILE(1,JN(J),JNIO)=0,C
IF (OFILE(JN(J),JNIO) .EQ. VMRR(K,51)) GO TO 70
XFILE(JN(J),JNIO)=OFILE(1,JN(J),JNIO)
OFILE(1,JN(J),JNIO)=0,C
XFILE(JN(J),JNIO)=OFILE(1,JN(J),JNIO)
OFILE(1,JN(J),JNIO)=0,C
IF (NPAIR(JNIX)) GE 2) GO TO 110
TTLD=TTLD(1,JNIX)+TTLD(2,JNIX)
RTTIM(JNIX)=2*RTTIM(JNIX,1)+TTLD(RL+TTLD/RU+CTUN+CTLU)
55 IF ((VMRK(K,14)+RTTIM(JNIX)) LE VMRK(K,2)) GO TO 56
K=K+1
IF (K GT NVI) GO TO 57
GO TO 55
57 NDEFO=NDEFO+1
IF (JOINT(JNIX,1)=0
IF (JOINT(JNIX,2)=0
NPR(JNIX)=4
GO TO 40
56 TV(JNIX)=K
VMRK(K,9)=VMRK(K,5)+1.
VMRK(K,10)=VMRK(K,10)+RTTIM(JNIX)
VMRK(K,14)=VMRK(K,14)+RTTIM(JNIX)
GO TO 40
70 TLOAD(1,JNIX)=VMRK(K,5)
IF (TFILE(1,JNIX)=GT. VMRK(K,5)) GO TO 80
OFILE(1,JNIX)=TFILE(1,JNIX)-VMRK(K,5)
IF (TFILE(2,JNIX)=GT. VMRK(K,6)) GO TO 90
75 TLOAD(2,JNIX)=TFILE(2,JNIX)
77 TFILE(1,JNIX)=GT. VMRK(K,6)
78 TFILE(2,JNIX)=GT. VMRK(K,6)
GO TO 110
90 TLOAD(2,JNIX)=VMRK(K,6)
IF (TFILE(2,JNIX)=GT. VMRK(K,6)) GO TO 100
GO TO 77
100 OFILE(2,JNIX)=OFILE(2,JNIX)-VMRK(K,6)
GO TO 110
80 OFILE(1,JNIX)=OFILE(1,JNIX)-VMRK(K,5)
IF (OFILE(2,JNIX)=GT. VMRK(K,6)) GO TO 85
TLOAD(2,JNIX)=OFILE(2,JNIX)
GO TO 78
85 TLOAD(2,JNIX)=VMRK(K,6)
OFILE(2,JNIX)=OFILE(2,JNIX)-TLOAD(2,JNIX)
110 TLOAD=TLOAD(1,JNIX)+TLOAD(2,JNIX)
RTTIM(JNIX)=RTTIM(JNIX)+RTTIM
111 IF ((VMRK(K,14)=VMRK(K,14)) LT. RTTIM) GO TO 115
VMRK(K,14)=VMRK(K,14)+RTTIM
IF (RTTIM=GT. VMRK(K,14)) GO TO 109
VMRK(K,15)=VMRK(K,15)+RTTIM-VMRK(K,1)
NTV(K)=NTV(K)+RTTIM
VMRK(K,1)=VMRK(K,1)+1
VMRK(K,10)=VMRK(K,10)+RTTIM(JNIX)
VMRK(K,11)=VMRK(K,11)+TLOAD(1,JNIX)+TLOAD(2,JNIX)
GO TO 116
115 K=K+1
IF (K GT NVI) GO TO 114
GO TO 111
114 NDEFO=NDEFO+1
IF (JOINT(JNIX,1)=0
IF (JOINT(JNIX,2)=0
NPR(JNIX)=4
GO TO 40
116 SMM(JNIX,1)=VMRK(JNIX,14)+1
ACCEPT=SMR(JNIX,2)-SMR(JNIX,8)
ACCEPT2=SMR(JNIX,3)-SMR(JNIX,9)
IF (ACCEPT LE TQUANT(JNIX)) GO TO 117
KFS0420
KFS04250
KFS04280
KFS04300
KFS04310
KFS04320
KFS04330
KFS04340
KFS04350
KFS04360
KFS04370
KFS04380
KFS04390
KFS04400
KFS04410
KFS04420
KFS04430
KFS04440
KFS04450
KFS04460
KFS04470
KFS04480
KFS04490
KFS04500
KFS04510
KFS04520
KFS04530
KFS04540
KFS04550
KFS04560
KFS04570
KFS04580
KFS04590
KFS04600
KFS04610
KFS04620
KFS04630
KFS04640
KFS04650
KFS04660
KFS04670
KFS04680
KFS04690
KFS04700
KFS04710
KFS04720
KFS04730
KFS04740
KFS04750
KFS04760
KFS04770
KFS04780
KFS04790
KFS04800
KFS04810
KFS04820
KFS04830
KFS04840
KFS04850
VMM(1,5) = VRMM(1,5) + TLAD(1, JNIDX) - ACEPTR
TLAD(1, JNIDX) = ACEPTR
LOAD = 1

117 IF ((ACEPTR + UE, TLAD(2, JNIDX)) GO TO 118
   VMM(1,5) = VRMM(1,5) + TLAD(2, JNIDX) - ACEPTR
   LOAD = 1
   TLAD(2, JNIDX) = ACEPTR
118 IF (LOAD = 1) GO TO 112
   VMM(1,3) = VRMM(1,3) + 1.
   OFILE(1, JNIDX) = 0, C
   OFILE(2, JNIDX) = 0, C
   SMRM(1, JNIDX, 8) = SMRM(1, JNIDX, 8) + TLAD(1, JNIDX)
   SMRM(1, JNIDX, 9) = SMRM(1, JNIDX, 9) + TLAD(2, JNIDX)
   SMRM(1, JNIDX, 6) = SMRM(1, JNIDX, 8)
   SMRM(1, JNIDX, 7) = SMRM(1, JNIDX, 9)
   SMRM(1, JNIDX, 13) = 1
   SMRM(1, JNIDX, 15) = SMRM(1, JNIDX, 15) + TLAD(1, JNIDX)
   SMRM(1, JNIDX, 16) = SMRM(1, JNIDX, 15) + TLAD(2, JNIDX)
   IF (NPFR(JNIDX), E.G. 21) GO TO 113
   IF ((OFILE(1, JNIDX) = GT, (UFVRMM(1,5)), OR, (OFILE(2, JNIDX)) GT KS05030)
      1, (UFVRMM(1,6))) GO TO 12
113 XFILE(1, JNIDX) = 0, C
   XFILE(2, JNIDX) = 0, C
   IF (OUTJNIDX,1) = 0
   IF (OUTJNIDX,2) = 0
   CONTINUE
   C

   C THIS SECTION CARRIES OUT THE CLARKE AND WRIGHT PROCEDURE FOR ROUTE
   C IMPROVEMENT
   C
   DO 45 J = 1, 2
      DO 45 K = 1, NSTAT
50 (OFILE(I, K) = XFILE(I, K))
   IF (IOUT(I, K)) > 0, 1, 102
   102 JDX = 2
      IDX = JDX - 1
      SAVX = 0, 0
      LSAX = 0
      ESAX = 0
      DO 120 K = 1, IU
         JNIDX = [NIDX]
         DO 121 JDX = 1
            JNIDX = [NIDX]
30 \{ \}
   120 CONTINUE
50 (SAVX(I, K) = 1, KINDEX) = L., SAVX(I, K) = 0, 0, 0
   IF ((IOUT(JNIDX, I) = E.G. 0) OR, (IOUT(JNIDX, I) = E.G. 0)) GO TO 120
   120 JDX = 2
      IDX = JDX - 1
      SAVX = 0, 0
      LSAX = 0
      ESAX = 0
      DO 120 K = 1, IU
         JNIDX = [NIDX]
         DO 121 JDX = 1
            JNIDX = [NIDX]
30 \{ \}
   120 CONTINUE
50 (SAVX(I, K) = 1, KINDEX) = L., SAVX(I, K) = 0, 0, 0
   IF ((IOUT(JNIDX, I) = E.G. 0) OR, (IOUT(JNIDX, I) = E.G. 0)) GO TO 120
   120 JDX = 2
      IDX = JDX - 1
      SAVX = 0, 0
      LSAX = 0
      ESAX = 0
      DO 120 K = 1, IU
         JNIDX = [NIDX]
         DO 121 JDX = 1
            JNIDX = [NIDX]
30 \{ \}
   120 CONTINUE
50 (SAVX(I, K) = 1, KINDEX) = L., SAVX(I, K) = 0, 0, 0
   IF ((IOUT(JNIDX, I) = E.G. 0) OR, (IOUT(JNIDX, I) = E.G. 0)) GO TO 120
   120 JDX = 2
      IDX = JDX - 1
      SAVX = 0, 0
      LSAX = 0
      ESAX = 0
      DO 120 K = 1, IU
         JNIDX = [NIDX]
         DO 121 JDX = 1
            JNIDX = [NIDX]
30 \{ \}
   120 CONTINUE
50 (SAVX(I, K) = 1, KINDEX) = L., SAVX(I, K) = 0, 0, 0
   IF ((IOUT(JNIDX, I) = E.G. 0) OR, (IOUT(JNIDX, I) = E.G. 0)) GO TO 120
   120 JDX = 2
      IDX = JDX - 1
      SAVX = 0, 0
      LSAX = 0
      ESAX = 0
      DO 120 K = 1, IU
         JNIDX = [NIDX]
127 CONTINUE
TRTIM=TRTIM(JNIDX)+TRTIM(KNIDX)+AJJR-CTLD
IF (TRTIM .GT. VMRRM(L,1,1)) GO TO 122
JSAV=JNIDX
KSAY=KNIDX
LSAV1=LADJ1
LSAV2=LADJ2
TRTEM=TRTIM
ADJRS=ADJRS
ADJO=-DIS(JSAV,1)+DIS(KSAV,1)+DIS(JSAV,1)+DIS(KSAV,1)
RTDIS=RTDIS(JSAV)+RTDIS(KSAV)+ADJU
GO TO 121
122 SAV(JNIDX-1,KNIDX)=9.
121 CONTINUE
120 KDX=KDX+1
IF (LSAV1.EQ.0) GO TO 123
TLOAD(1,JSAV)=-5+VMRRM(1,5)
TLOAD(1,KSAV)=-5+VMRRM(1,5)
123 IF (LSAV2.EQ.0) GO TO 124
TLOAD(2,JSAV)=-5+VMRRM(1,6)
TLOAD(2,KSAV)=-5+VMRRM(1,6)
124 IF (LSAV1.EQ.0) GO TO 170
SAVE(JSAV,1,KSAV)=9.
RTNE=RTTIM(JKSAV)+JDOJS-CTLD
IF (VMRRM(JVJSAV,1,4)+RTNE .GT. VMRRM(JVJSAV,1,2)) GO TO 130
NVHM=IVJSAV
VMRM=IVKSAV
VMRM=IVKSAV,91=VMRM(JVJSAV,91,-1)
VMRM(JVJSAV,1,4)=VMRM(JVJSAV,1,4)-RTTIM(KSAV)
VMRM(IVJSAV,1,4)+VMRM(IVJSAV,1,4)+RTNE
VMRM(IVJSAV,10,1)+VMRM(IVJSAV,10,1)+RTDIS(IIJSAV)
VMRM(IVJSAV,10,1)=VMRM(IVJSAV,10,1)+RTDIS(IJSVAV)+ADJO
GO TO 125
110 RTTEM=RTTIM(JJSVAV)+JDOJS-CTLD
IF (VMRM(IVJSVAV,1,4)+RTNE .GT. VMRM(IVJSVAV,21)) GO TO 140
NVHM=IVKSAV
VMRM=IVJSVAV,91=VMRM(IVJSVAV,91,-1)
VMRM(IVJSVAV,1,4)=VMRM(IVJSVAV,1,4)-RTTIM(JJSVAV)
VMRM(IVJSVAV,10,1)+VMRM(IVJSVAV,10,1)+RTDIS(IIJSVAV)
VMRM(IVJSVAV,10,1)=VMRM(IVJSVAV,10,1)+RTDIS(IJSVAV)+ADJO
GO TO 125
140 CU 160 KX=0
IF (VMRM(KX,1,14)+RTTIMS .GT. VMRRM(KX,21)) GO TO 150
NVHM=KX
IF (IVJSVAV.EQ.0) GO TO 149
VMRM(IVJSVAV,91)=VMRM(IVJSVAV,91,1)
VMRM(IVJSVAV,1,4)=VMRM(IVJSVAV,1,4)-RTTIM(KSAV)
VMRM(IVJSVAV,10,1)+VMRM(IVJSVAV,10,1)+RTDIS(IIJSVAV)
VMRM(IVJSVAV,10,1)=VMRM(IVJSVAV,10,1)+RTDIS(IJSVAV)
VMRM(IVJSVAV,10,1)=VMRM(IVJSVAV,10,1)+RTDIS(IIJSVAV)
VMRM(IVJSVAV,10,1)=VMRM(IVJSVAV,10,1)+RTDIS(IJSVAV)
GO TO 125
150 IF (KX .NE. NV) GO TO 160
GO TO 165
160 CONTINUE
125 IF (TROUT(KSAV,2) .NE. -9) GO TO 400
IF (IROUT(JZAV,3) .NE. -9) GO TO 480
IROUT(KSAV,2)=JSAV
IROUT(JZAV,3)=KSAV
GO TO 500
400 IF (IROUT(JZAV,2) .NE. -9) GO TO 450
IROUT(JZAV,2)=KSAV
IROUT(JZAV,3)=JSAV
GO TO 500
450 JX=JSAV
475 IDUM=IROUT(JX,2)
IROUT(JX,2)=IROUT(JX,3)
IROUT(JX,3)=IDUM
IF (IROUT(JX,3) .EQ. -9) GO TO 490
JX=IROUT(JX,3)
GO TO 475
490 IROUT(JZAV,2)=KSAV
IROUT(KSAV,3)=JSAV
GO TO 500
480 JX=JSAV
485 IDUM=IROUT(JX,3)
IROUT(JX,3)=IROUT(JX,2)
IROUT(JX,2)=IDUM
IF (IROUT(JX,2) .EQ. -9) GO TO 510
JX=IROUT(JX,2)
GO TO 485
510 IROUT(JZAV,3)=KSAV
IROUT(KSAV,2)=JSAV
500 JX=JSAV
520 IF (IROUT(JX,2) .EQ. -9) GO TO 530
JX=IROUT(JX,2)
GO TO 520
530 KX=KSAV
540 IF (IROUT(KX,3) .EQ. -9) GO TO 550
KX=IROUT(KX,3)
GO TO 540
550 TLOAD(1,JX)=TLOAD(1,JS)AV)+TLOAD(2, KSAV)
TLOAD(1,KX)=TLOAD(1,JX)
TLOAD(2,JX)=TLOAD(2, JS)AV)+TLOAD(2, KSAV)
TLOAD(2,KX)=TLOAD(2,JX)
XFILE(1,KX)=XFILE(1,KSAV)+XFILE(1,JS)AV)
XFILE(2,KX)=XFILE(2,KSAV)+XFILE(2,JS)AV)
XFILE(1,JX)=XFILE(1,KX)
XFILE(2,JX)=XFILE(2,KK)
IROUT(JZAV,1)=IROUT(JSAV,1)+IROUT(JZAV,1)-1
IROUT(KSAV,1)=IROUT(KSAV,1)+1
RTTIM(JX)=RTTIM
RTTIM(KX)=RTTIM
RTDIS(JX)=RTDIS
RTDIS(KX)=RTDIS
TVXJX)=VH
TVXX)=VW
IROUT(KSAV,4)=IROUT(KX,4)
IROUT(JSAV,4)=IROUT(JX,4)
IROUT(JZAV,4)=IROUT(JX,4)
165 IF (JSAVK .GT. 0.0) GO TO 119
C
C STATION STATISTICS UPDATE
C
170 DO 300 J=1,NSTAT
IF (IROUT(JX,2) .NE. -9) GO TO 300
JNXD=J

175 IF (XFILE(I,J) .GT. 1.0) GO TO 176
FACT=0.0
GO TO 177
176 FACT=TLADO(I,J)/XFILE(I,J)
177 IF (XFILE(I,J) .GT. 0.1) GO TO 178
FACT=0.0
GO TO 179
178 FACT=TLADO(I,J)/XFILE(I,J)

CONTINUE

ACEPFR=SMRMLIN(JDX,1)=SMRMLIN(JDX,8)
IF (ACEPFR .GT. (FACT*XFILE1(I,JNDX))) GO TO 180
SMRMLIN(JDX,8)=SMRMLIN(JDX,1)+ACEPFR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+ACEPFR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+ACEPFR
TLADO(I,J)=TLADO(I,J)-ACEPFR
GO TO 190

180 DEVR=FACT*XFILE1(I,JNDX)
SMRMLIN(JDX,8)=SMRMLIN(JDX,8)+DEVR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+DEVR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+DEVR
TLADO(I,J)=TLADO(I,J)-DEVR
GO TO 190

190 ACETP=SMMRMLIN(JDX,7)=SMRMLIN(JDX,9)
IF (ACETP .GT. (FACT*XFILE2(I,JNDX))) GO TO 205
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ACETP
SMRMLIN(JDX,7)=SMRMLIN(JDX,9)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ACETP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ACETP
TLADO(2,J)=TLADO(2,J)+ACETP
GO TO 210

205 ENDP=FACT*XFILE2(I,JNDX)
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ENDP
SMRMLIN(JDX,7)=SMRMLIN(JDX,7)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ENDP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ENDP
TLADO(2,J)=TLADO(2,J)+ENDP
GO TO 210

210 JNDX=J

175 IF (XFILE(I,J) .GT. 1.0) GO TO 176
FACT=0.0
GO TO 177
176 FACT=TLADO(I,J)/XFILE(I,J)
177 IF (XFILE(I,J) .GT. 0.1) GO TO 178
FACT=0.0
GO TO 179
178 FACT=TLADO(I,J)/XFILE(I,J)

CONTINUE

ACEPFR=SMRMLIN(JDX,1)=SMRMLIN(JDX,8)
IF (ACEPFR .GT. (FACT*XFILE1(I,JNDX))) GO TO 180
SMRMLIN(JDX,8)=SMRMLIN(JDX,1)+ACEPFR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+ACEPFR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+ACEPFR
TLADO(I,J)=TLADO(I,J)-ACEPFR
GO TO 190

180 DEVR=FACT*XFILE1(I,JNDX)
SMRMLIN(JDX,8)=SMRMLIN(JDX,8)+DEVR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+DEVR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+DEVR
TLADO(I,J)=TLADO(I,J)-DEVR
GO TO 190

190 ACETP=SMMRMLIN(JDX,7)=SMRMLIN(JDX,9)
IF (ACETP .GT. (FACT*XFILE2(I,JNDX))) GO TO 205
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ACETP
SMRMLIN(JDX,7)=SMRMLIN(JDX,9)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ACETP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ACETP
TLADO(2,J)=TLADO(2,J)+ACETP
GO TO 210

205 ENDP=FACT*XFILE2(I,JNDX)
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ENDP
SMRMLIN(JDX,7)=SMRMLIN(JDX,7)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ENDP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ENDP
TLADO(2,J)=TLADO(2,J)+ENDP
GO TO 210

210 JNDX=J

175 IF (XFILE(I,J) .GT. 1.0) GO TO 176
FACT=0.0
GO TO 177
176 FACT=TLADO(I,J)/XFILE(I,J)
177 IF (XFILE(I,J) .GT. 0.1) GO TO 178
FACT=0.0
GO TO 179
178 FACT=TLADO(I,J)/XFILE(I,J)

CONTINUE

ACEPFR=SMRMLIN(JDX,1)=SMRMLIN(JDX,8)
IF (ACEPFR .GT. (FACT*XFILE1(I,JNDX))) GO TO 180
SMRMLIN(JDX,8)=SMRMLIN(JDX,1)+ACEPFR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+ACEPFR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+ACEPFR
TLADO(I,J)=TLADO(I,J)-ACEPFR
GO TO 190

180 DEVR=FACT*XFILE1(I,JNDX)
SMRMLIN(JDX,8)=SMRMLIN(JDX,8)+DEVR
SMRMLIN(JDX,6)=SMRMLIN(JDX,8)
SMRMLIN(JDX,15)=SMRMLIN(JDX,15)+DEVR
VMRMI(VJ,J,11)=VMRMI(VJ,J,11)+DEVR
TLADO(I,J)=TLADO(I,J)-DEVR
GO TO 190

190 ACETP=SMMRMLIN(JDX,7)=SMRMLIN(JDX,9)
IF (ACETP .GT. (FACT*XFILE2(I,JNDX))) GO TO 205
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ACETP
SMRMLIN(JDX,7)=SMRMLIN(JDX,9)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ACETP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ACETP
TLADO(2,J)=TLADO(2,J)+ACETP
GO TO 210

205 ENDP=FACT*XFILE2(I,JNDX)
SMRMLIN(JDX,9)=SMRMLIN(JDX,9)+ENDP
SMRMLIN(JDX,7)=SMRMLIN(JDX,7)
SMRMLIN(JDX,16)=SMRMLIN(JDX,16)+ENDP
VMRMI(VJ,J,13)=VMRMI(VJ,J,13)+ENDP
TLADO(2,J)=TLADO(2,J)+ENDP
GO TO 210

210 JNDX=J
SUBROUTINE REPORT1,CR,CP,CD,CM,CP,CMT,COP,CLT,LRT,IRPT

COMMON SMRM(25,181), VPM(10,16), X(10), Y(10), X(10), Y(10), YHKS, KF507240
110, Y(10), X(10), COF(10,251), IT(25), ST2(25,2), NST2, NV, NHMK, NREL, KF507250
2AVRL, MU, DF, UF, CTAU, CILD, TUNT, NDEFO, NSFS, SHTR, SHTP, KF507260
COMMON/HWK,TIM(25,25), DIS(25,25), SAV(25,25), CM(25,25), QFILE(KF507270)
12525, NPRT(25), KF507280
RPRT=1/IRPT
NWS=1L-IRPT
WKS=1WS
CYS=1-LRT-NWKS*7
STM=1
SFRN=NSFS
WRITE(14400,650) STM

850 FORMAT('ILP5X* SIMULATED TIME ','F5.0,1')
WRITE(14400,870) RPRT

870 FORMAT('5X* REPORT PERIOD ','F5.0,1')

STM=1-LRT
LRT=1

C

VEHICLE STATISTICS

WRITE(14400,1000)

1000 FORMAT('5X* VEHICLE STATISTICS','//')

TDC=0.0
TMC=0.0
TDC=0.0
TLC=0.0
TFC=0.0
TNT=0.0
TAV=0.0
TAL=0.0
TAT=0.0
TNG=0.0
TNEX=0.0
TUND=0.0
TIVO=0.0

WRITE(14400,940)

940 FORMAT(' VEHICLE','3X','TOTAL','5X','AVERAGE','4X','AVERAGE','3X','AVERAGE','5X','AVERAGE',KFS07640
11X2X','AVERAGE','4X','NUMBER OF','5X','VEHICLE','6X','VEHICLE','5X','VEHICLE','I KFS07650
ZLE','4X','COST OF','4X','TOTAL','4X','NUMBER','4X','NUMBER','4X','NUMBER','4X','KFS07660
2AVR','TRIP','4X','TRIP','4X','TRIPS','4X','TRIPS 'KFS07670
41X3X','MAINTAINENCE','3X','DRIVER','4X','TAXES ANU','3X','COST','//','LX',JFK507680
51X5X','TRIPS PER','5X','LENGTH','5X','TIME','4X','DELIVERED','5X','EAGCESS','KFS07690
6X','COST','10X','COST','8X','COST','5X','LICENSING','KFS07700

WRITE(14400,950)

950 FORMAT('5X*LOAD1','7X','LOAD2','7X','LOAD3','7X','LOAD4')

GO 200 J=1,NV

VR=NV
AVTR=VMR(K,J)/TIM
IF (VRHMK(K,J) GT 0.0) GO TO 955

ATL=0.0
ATT=0.0
AGT=0.0

GO TO 956

955 ATL=VMRM(K,J,1)/VMR(K,J)
ATT=VMRM(K,J,2)/VMR(K,J)
AGT=VMRM(K,J,3)/VMR(K,J)

KFS07720
KFS07730
KFS07740
KFS07750
KFS07760
KFS07770
KFS07780
KFS07790
KFS07800
KFS07810
KFS07820
KFS07830


WRITE (NWRIT, 910)

910 FORMAT (1X, 'TOTAL', 12X, 'AVERAGE', 14X, 'AVG DIARY', 12X, 'AVG', 12X, 'AVG')

WRITE (NWRIT, 920)

920 FORMAT (2X, 'TOTAL', 12X, 'AVERAGE', 14X, 'AVG')

C

C STATISTICS RESET

C

C
TAIP=TAIP/STIM
TAOMR=TAOMR/STIM
TAOMP=TAOMP/STIM
WRITE(1,WRI,93G1) ING, TAOMR, TAOMP, TAOSR, TAOSP, TAIR, TAIP, TIG
ITKP
930 FORMAT(* TOTAL*,10X,F4.0,8X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,4X,F7.1,4X,F9.1)
12X,F9.1,5X,F9.2,7X,F4.0)
TAVCST=(TFC+TIG)/T50L0
WRITE(1,WRI,935) TAVCST, 'NDEFO, SHTR, SHTP
935 FORMAT(//,' AVERAGE TOTAL COST*,F8.5,' PER GALLON SOLD*,//,' NUMBER
1 OF DEFERRED ORDERS*,15X,' LOST SALES REGULAR*,F8.1,' GALLONS*,//,' LOST SALES PREMIUM*,F8.1,' GALLONS*)
NDEFO=0
SHTR=0.0
SHTP=0.0
RETURN
END
NON-COMPARTMENTALIZED VEHICLES PROGRAM
THE MAIN PROGRAM READS IN ALL INITIAL VALUES OR PRESETS THEM FOR THE INITIAL
BEGINNING OF THE SIMULATION, AS WELL AS KEEPS TRACK OF TIME AND THE CURREN'T EVENT.

COMMON SHRM(25,15), VHRM(10,161), X1(10), XM1D(1), XX1D(1), Y1(10), YNM(10), YTH(10), YTH(10),
YV(10), YXV2(10), CP(10,25), ITL(25), ST2(25,25), NSTAT, NV, NWIT, NREK
2AD, RL, RU, UF, UF, CTUN, CTUL, TUN, NUEFU, NSEF, SHTR, SHIP
COMMON/N1/N2/N3/N4/N5/N6
12, 25), NPK(2,25)
DIMENSION P(20)

C
INITIALIZATION

NREAD=5
NWRITE=6
P=1.415927
DO 4 I=1,2
DO 4 J=1,25
4 NPR(I,J)=0
DO 5 I=1,25
DO 5 J=1,19
5 SHRM(I,J)=0.0
DO 10 I=1,25
DO 10 J=1,25
DIS(I,J)=0.0
DO 20 I=1,25
20 CM1(I,J)=0.0
DO 15 I=1,10
DO 15 J=1,16
15 VMK(I,J)=0.0
TUNF=0.0
SHTR=0.0
SHIP=0.0

C
READ IN DATA

READ(NREAD1,1000) NSTAT, NV, NC, NT, NM, NSP, NWP, ITIM, ICH, IRPT
1000 FORMAT(15,110,15)
READ(NREAD2,1005) CR, CP, CG, CD, CMT, GCP, CLT, RL, RU, UF, UF, CTU
1005 FORMAT(15,110,15)
READ(NREAD3,1005) IJ
1000 FORMAT(15,110,15)
READ(NREAD4,1005) IJ
17 Y(J)=CS2*(P/J)(P/J)
DO 18 I=1,NM
18 READ(NREAD5,1005) (COF(I,J),J=1,NM)
1005 FORMAT(10,F10.4)
DO 19 I=1,NSTAT
19 READ(NREAD6,1005) IT1(I), ST1(I,1), ST2(I,2)
1005 FORMAT(10,210,4)
DO 20 I=1,NSTAT
20 READ(NREAD7,1020) (SHRM(I,J),J=1,NSP)
1020 FORMAT(10,F8.2)
DO 30 I=1,NV
30 READ(10,READ),IO2(1,VARH(I,J),J=1,NV)
   I=1,NSTAT
   READ(10,READ),ICIS(I,J,J=1,IDX)
1030 FORMAT(20F4.1)
   IDX=IDX+1
   I=1,IDX
   DO 50 I=1,NSTAT
      READ(10,READ),TIMI(J),J=1,IDX
   50 IDX=IDX+1
   C CALCULATE SAVINGS FOR CLARKE AND WRIGHT PROCEDURE IN TERMS OF THE TOTAL KFS00720
   C TRANSPORTATION COST
      KFS00730
   C
      KFS00740
      IDX=1
      DO 65 I=1,NSTAT
         DO 75 J=1,IDX
         65 IDX=IDX+1
      75 J=J+1
      60 CM(I,J)=CM(I,J)+(CM+CORP*OSI(I,J))
      65 IDX=IDX+1
      JDX=NSTAT+1
      IDX=1
     60 J=J+1
     70 CONTINUE
      KFS00870
   C ECHO CHECK
     KFS00890
     IF (ICH. EQ. 0) GC TO 300
     WRITE(*,1040)
     1040 FORMAT(1X,* ECHO CHECK OF INPUT DATA */**/)
     WRITE(*,1050) ITIM, NSTAT, NV, NSFITS, NSP, NVP, NM, NC, NJ, IAKF50010
     1050 FORMAT(1X,19X,TOTAL SIMULATED TIME *,/15X,GAYS,*/19X,NUMBER OF TFKFS00470
            1STATIONS*,/19X,NUMBER OF VEHICLES *,/19X,NUMBER OF CMKFS00490
            2STATIONS*,/19X,NUMBER OF VEHICLE CHARACTERISTICS INPUT *,/19X,KFS00470
            3V*,NUMBER OF VEHICLE CHARACTERISTICS INPUT *,/19X,KFS00470
            4V MODELS*,/19X,NUMBER OF MODEL TERMS *,/19X,NUMBER OF CMKFS00490
            5 TRIG. TERMS*,/19X,SEED VALUE *,/19X)
     WRITE(*,1060) CR, CP, CC, CD, CM, COP, CLT
     1060 FORMAT(1X,REGULAR GASOLINE AT THE TERMINAL *,/19X,PFKFS01010
            1ER GALLON*,/19X,COST OF PREMIUM GASOLINE AT THE TERMINAL *,/19X,KFS01010
            2*,/19X,INVENTORY CARRYING COST (S PRODUCT COST *) KFS01010
            3*,/19X,PER YEAR*,/19X,DRIVERS WAGES *,/19X,PER HOUR*,/19X, KFS01040
            4VEHICLE MAINTENANCE COST *,/19X,PER MILE*,/19X,VEHICLE OPERAFKFS01050
            5ING COST *,/19X,PER MILE*,/19X,TAXES AND LICENSING *,/19X, KFS01070
            6PER VEHICLE PER YEAR*)
     WRITE(*,1065) CTLD, HL, CTUN, RU, DF, UF
     1065 FORMAT(1X,LOADING RATE*,/19X,LOADING FACTOR*,/19X,MOOKFS01100
            2*,/19X,UNLOADING RATE*,/19X,DELIVERY FACTOR*,/19X, KFS01110
            3*,/19X,MINIMUM UNLOADING FACTOR *,/19X)
     WRITE(*,1070)
     1070 FORMAT(1X,MODEL COEFFICIENTS,*)
     WRITE(*,1075) (J,J=1,NM)
     1075 FORMAT(X,10(I0,1,1))
     ND=100
     WRITE(*,1080) (J,J=1,NM)
     1080 FORMAT(10X,10(I0,10X,4))
CLT=CLT*RPT

C EVENT SCHEDULING AND MONITORING

I=1
100 IDX=I/I\RPT
100 IDX=IDX\RPT
CALL STDAY11, NC, NT, NM, I\X
IF (IDX .EQ. 0) GO TO 210
GO TO 220
210 CALL RPORT11, CR, CF, CC, CD, CH, CP, CLT, LRT, I\RPIT
220 IF (I .EQ. IT\K) GO TO 200
I=I+1
GO TO 110
200 CONTINUE
STOP
END
SUBROUTINE STDAY1G(CNT, XM, IX)

C THIS SUBROUTINE MAKES THE DAILY FORECASTS AND UPDATES THE PREDICTED AND ACTUAL INVENTORY STATUS FOR EACH ESTATE. THE PREDICTED AND ACTUAL INVENTORY STATUS FILES ARE CHECKED AGAINST SAFETY LEVELS TO DETERMINE THE DAY'S DELIVERY FILE.

COMMON SMRM(25,191), VDRM(10,16), X(10), XM(10), Y(10), VD(125), YD(25,2), NSTAT, NV, NARIT, VREDS(25,25), 2DQ, LK, AN, DF, UF, CTIC, CTIL, TUNT, NUEFD, NSFIL, SFTIL, SFTIL, SHF

COMMON AXWKM(125), AxWKM(25,25), SSAX(25,25), C1(25,25), OFILE

DIMENSION VCM(303), TUT(101), RUN(21), WDM(25,4)

IDX=1/7
INDEX=INDEX-7
PL=3.415527
IF (INDEX .EQ. 0) GO TO 8

C RESET VEHICLE DAILY MILEAGE TOTALS, UPDATE INVENTORY RECORDS

DO 1 J=1, NV
1 VDRM(J,14)=0.0
DO 2 J=1, NSTAT
2 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
DO 3 J=1, NV
3 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
DO 3 K=1, NSTAT
4 IF (NPJK(J,K) .EQ. 0) GO TO 3
5 NPM(J,K)=0
6 CONTINUE
7 GO TO 1
8 IF (IDX=1,NSTAT
7 OFILE(J,JX)=0.0
GO TO 15

C SET UP ITERATIVE SIN - GCS ROUTINE

15 DO 10 J=1, NT
10 XJ(J)=SMRM(J,11)+SMRM(J,9)
Y(J)=SMRM(J,11)-SMRM(J,9)
10 CONTINUE
GO TO 120

C CREATE MULTIPLIER VECTOR

C
GO 20 J=1,30
20 VCM(J)=0.0
SI=1
VCM(1)=1.0
VCM(2)=1
VCM(3)=1/10000.
JDX=6
DO 30 J=1,NT
VCM(JDX+1)=XX(J)
VCM(JDX+1)=YY(J)
30 JDX=JDX+2
IF (IDX.EQ.0) GO TO 35
VCM(16)+IDX=1.0
35 CONTINUE
DO 40 J=1,NM
40 TOT(J)=0.0
GO TO 50
50 TOT(JK)+TOT(JX)+VCM(J)+CDF(JX,J)
DO TO J=1,NSTAT
DRF=TOT(J(JJ))+ST2(J,J)
DPF=TOT(J(JJ)+NK/J)+ST2(J,J)
C
GENERATE "RANDOM" VARIATION
C
DO 55 JX=1,2
55 RN=RN(JX)+CDF(JX+1 J J, NC)
C
UPDATE STATUS, CREATE ORDER FILE
C
IF (IDX.EQ.0) GO TO 65
DRA=DRF+RN(1)
IF (DRA+0.0) DRA=0.0
IF (DRA+0.0) DRA=0.0
56 SMRM(J,J)+SMRM(J,J)+DRA
SMRM(J,J)+SMRM(J,J)+DRA
IF (SMRM(J,J)+GT.0.0) GO TO 54
SHIP=SHIP+SMRM(J,J)
SMRM(J,J)+0.0
54 SMRM(J,J)+SMRM(J,J)+DRA
IF (NPRL(J,J)+NE.4) GO TO 60
SMRM(J,J)+SMRM(J,J)+DRA
NPRL(J,J)+2
GO TO 61
60 IF ( ( ( ( (SHRM(J,6) - SHRM(J,4)) .GT. 0.0 ) GO TO 57
NPR(J,J)=1
GO TO 58
61 OFILE(I,J)=SHRM(J,2)-SHRM(J,6)+DRF
GO TO 58
57 IF ( ( ( (SHRM(J,8)-SHRM(J,4)) .GT. 0.0 ) GO TO 58
NPR(J,J)=2
OFILE(I,J)=SHRM(J,2)-SHRM(J,8)
GO TO 58
58 IF ( ( NPR(J,J) .NE. 4 ) GO TO 59
NPR(J,J)=3
GO TO 58
59 IF ( ( ( (SHRM(J,1)-SHRM(J,5)) .GT. 0.0 ) GO TO 59
NPR(J,J)=1
GO TO 58
52 OFILE(I,J)=SHRM(J,3)-SHRM(J,7)+DPF
GO TO 52
52 IF ( (DPF .GE. 0 ) GO TO 59
NPR(J,J)=2
OFILE(I,J)=SHRM(J,3)
GO TO 52
59 IF ( ( ( (SHRM(J,9)-SHRM(J,5)) .GT. 0.0 ) GO TO 59
NPR(J,J)=2
GO TO 59
C DETERMINE SUNDAY DEPAND FOR CREATION OF SATURDAY ORDER FILE.
C 65 DRA=DRF+RN(1)
DPA=DPF+RN(2)
IF ( ( (DPF .GE. 0 ) DPF=0.0
IF ( ( (DRA .GE. 0.0 ) DRA=0.0
IF ( ( (DPA .GE. 0 ) DPA=0.0
WED(J,3)=CRA
WED(J,1)=CRA
WED(J,2)=CRA
WED(J,4)=CRA
SMM(J,1)=SHRM(J,1)+ECP(J,1)
SMM(J,2)=SHRM(J,2)+ECP(J,2)
SMM(J,3)=SHRM(J,3)+ECP(J,3)
SMM(J,4)=SHRM(J,4)+ECP(J,4)
SMM(J,5)=SHRM(J,5)+ECP(J,5)
SMM(J,6)=SHRM(J,6)+ECP(J,6)
C 70 CONTINUE
IF ( ( (IX .GE. 0 ) GT IC 75
IF ( ( (IX .LE. 6 ) IC TO 11C
NPR(J,J)=0
GO TO 15
75 IC IC+1,NSTAT
IF ( ( (NPR(J,J) .LE. 0 ) GO TO 85
80 IF ( ( ( (SHRM(J,6)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 82
NPR(J,J)=1
GO TO 85
81 IF ( ( ( (SHRM(J,8)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=2
GO TO 85
82 IF ( ( ( (SHRM(J,1)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=3
GO TO 85
83 IF ( ( ( (SHRM(J,2)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=4
GO TO 85
84 IF ( ( ( (SHRM(J,3)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=5
GO TO 85
85 IF ( ( ( (SHRM(J,4)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=6
GO TO 85
86 IF ( ( ( (SHRM(J,5)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=7
GO TO 85
87 IF ( ( ( (SHRM(J,6)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=8
GO TO 85
88 IF ( ( ( (SHRM(J,7)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=9
GO TO 85
89 IF ( ( ( (SHRM(J,8)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=10
GO TO 85
90 IF ( ( ( (SHRM(J,9)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=11
GO TO 85
91 IF ( ( ( (SHRM(J,10)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=12
GO TO 85
92 IF ( ( ( (SHRM(J,11)-WECH(J,1)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=13
GO TO 85
93 IF ( ( ( (SHRM(J,12)-WECH(J,3)-SHRM(J,4)) .GT. 0.0 ) GO TO 85
NPR(J,J)=14
GO TO 85
SPRM(J,13)=SPRM(J,13)+1.
100 CONTINUE
110 CALL POUT(I)
120 RETURN
END
SUBROUTINE ROUT(I1)
COMMON SMKM(25,19), VMKM(10,16), XI(10), XH(10), XX(10), Y1(10), YH(KF050380)
101, Y1(10), COFI(25,25), ILT(25), ST(25,2), NSTAT, NV, NWRT, NREK(KF0501840)
2AD, RL, KG, UF, UP, CIN, CILU, TNL, NUEFO, NFSTS, SNH, SMBF KF0503850
L(25), NPR(25,25) KF0503870
DIMENSION SAV(25,25), M(25,25), TRGT(25,4,1), TLAD(25,25), RRTIM(25) KF0503880
1, IV(25), AFILE(25,1), RTDIS(25,1), GVT(I10)
COMMON KF0503890
STK=NFSTS KF0503900
S=1
1 CO 2 K=1, NSTAT KF0503910
XFILE(K)+=0.0 KF0503920
2 TLAD(K)+=0.0 KF0503930
CO 3 J=1, NSTAT KF0503940
3 RTDIS(I1)=2.*DIS(I1+1) KF0503950
4 GVT(I1)+=0.0 KF0503960
C INITIALIZE SAVINGS MATRIX
C DO 5 J=1, NSTAT KF0503970
5 SAV(J,K)=SAV(J,K) KF0503980
C ESTABLISH INDIRECT INDEX
C IND=15W-1 KF0503990
JDX=0
6 DO 20 K=1, NSTAT KF0504000
IF (NPR(K)+.GT. 0) GO TO 10 KF0504010
GO TO 20 KF0504020
20 CONTINUE KF0504030
10 JDX=JDX+1 KF0504040
INDX(JDX)+=K KF0504050
21 IF JDX.EQ.0 GO TO 305 KF0504060
22 CO 30 J=1, NSTAT KF0504070
30 J=1 KF0504080
30 CONTINUE KF0504090
70 IRUFI(J,K)=0 KF0504100
C THIS SECTION MAKES THE INITIAL ALLOCATION OF VEHICLES TO SINGLE STAT
C IF N+ ROUTES
C K=1 KF0504110
60 DO J=1, JDX KF0504120
JNIDX=INDX(J) KF0504130
IF (JFILE(J+JNIDX).LE. (UP+VMKM(1,K,1))) GO TO 40 KF0504140
IRUFI(J+JNIDX)=K KF0504150
IF (JFILE(J+JNIDX).G.E. VMKM(K,5)) GO TO 70 KF0504160
TLDAD(J+JNIDX)=UFILE(J+JNIDX) KF0504170
UFILE(J+JNIDX)=INDX(J+JNIDX) KF0504180
UFILE(J+JNIDX)+=C.0 KF0504190
IF (SFILE(J+JNIDX).LE. 2) GO TO 110 KF0504200
TLDAD+TLD(J+JNIDX) KF0504210
INRTM(J+JNIDX)=2.*TM(JNIDX,1)+TTLAD+RL+TTLAD+RV+CTUMP+CUD KF0504220
IF (JFILE(J+JNIDX).LE. VMKM(2,K)) GO TO 56 KF0504230
K=K+1 KF0504240
IF (K+1.GT. NV) GO TO 57 KF0504250
GO TO 55

57 NDEFO=NLEFO+1
IROUTJNIDX+1=0
IROUTJNIDX+2=0
NPR(ISWJNIDX)=4
GO TO 40

56 IVJNIDX=K
VMRK(K,9)=VMRK(K,5)+1
VMRK(K,10)=VMRK(K,10)+RDISJNIDX
VMRK(K,14)=VMRK(K,14)+RTTIMJNIDX
GO TO 40

70 FILEJNIDX=VMRK(K,5)
IF (DFILE(ISWJNIDX).GT. VMRK(K,5)) GO TO 80
DFILE(ISWJNIDX)=0
GO TO 110

80 FILEJNIDX=DFILE(ISWJNIDX)-VMRK(K,5)
TTLDO=TLOADJNIDX
TTIM=2.141414JNIDX+1+TTLDO/CL+CTLD
RTTIMJNIDX=TTIM

110 IF (VMRK(K,2).LT. TTIM) GO TO 115
VMRK(K,14)=VMRK(K,14)+TTIM
IF (TTIM.LT. VMRK(K,7)) GO TO 109
VMRK(K,8)=VMRK(K,8)+TTIM-VMRK(K,7)
DVT(K)=DVT(K)+1
VMRK(K,7)=VMRK(K,7)+1
GO TO 115

115 K=K+1
IF (K.GT. NV) GO TO 114
GO TO 110

114 NDEFO=NDEFO+1
IROUTJNIDX+1=0
IROUTJNIDX+2=0
NPR(ISWJNIDX)+4
GO TO 40

116 SMRKJNIDX,14+INEC*5)+SMRKJNIDX,14+INOC*5)+1
ACCT=SMRKJNIDX,14+INEC*5)+SMRKJNIDX,7+1SW)+1
IF (ACCT.EQ. TLOADJNIDX) GO TO 117
VMRK(K,13)=VMRK(K,13)+1
TLOADJNIDX=ACCT
VMRK(K,13)=VMRK(K,13)+1
DFILE(ISWJNIDX)=0

117 SMRKJNIDX,14+INEC*5)=SMRKJNIDX,14+INOC*5)+1
SMRKJNIDX,7+1SW)+SMRKJNIDX,14+15W)+TLOADJNIDX
SMRKJNIDX,14+15W)+SMRKJNIDX,7+1SW)+TLOADJNIDX
IF (NPR(ISWJNIDX).LT. 2) GO TO 113
IF (DFILE(ISWJNIDX).GT. UM+VMRK(K,5)) GO TO 51

113 FILEJNIDX=0
IROUTJNIDX+1=0
IROUTJNIDX+2=0
CONTINUE

C THIS SECTION CARRIES OUT THE CLARKE AND WRIGHT PROCEDURE FOR ROUTE IMPROVEMENT

C

C GO 45 K=1,NSTAT
45 DFILE(ISW,K)=DFILE(K)
IF (JNE .LE. 1) GC TO 170

119 KDX=2
VPRM(I00(19A), 9) = VPRM(I00(19A), 9) - 1.
VPRM(I00(19A), 10) = VPRM(I00(19A), 10) - RTDIS(19A).
145 VPRM(I00(19A), 9) = VPRM(I00(19A), 9) - 1.
VPRM(KX, 9) = VPRM(KX, 9) - 1.
VPRM(KK, 14) = VPRM(KK, 14) - RTDIS.
VPRM(KK, 14) = VPRM(KK, 14) + RTDIS.
VPRM(I00(19A), 10) = VPRM(I00(19A), 10) - RTDIS.
VPRM(KX, 10) = VPRM(KX, 10) + RTDIS.
GO TO 125
150 IF (KX .NE. NVI) GO TO 160
GO TO 165
160 CONTINUE
125 IF (IROUT(I00(19A), 2) .NE. -9) GO TO 400
IF (IROUT(I00(19A), 3) .NE. -9) GO TO 480
IROUT(I00(19A), 2) = I00(A).
IROUT(I00(19A), 3) = I00(A).
GO TO 500
400 IF (IROUT(I00(19A), 2) .NE. -9) GO TO 450
IROUT(I00(19A), 2) = KSAV.
IROUT(I00(19A), 3) = I00(A).
GO TO 500
450 JX = I00(A).
475 TDUM = IROUT(JX, 2).
IROUT(JX, 2) = IROUT(JX, 2).
IROUT(JX, 1) = TDUM.
IF (IROUT(JX, 3) .EQ. -9) GO TO 490
JX = IROUT(JX, 3).
GO TO 475
490 IROUT(I00(19A), 2) = KSAV.
IROUT(I00(19A), 3) = I00(A).
GO TO 500
500 JX = I00(A).
510 TDUM = IROUT(JX, 3).
IROUT(JX, 1) = TDUM.
IF (IROUT(JX, 2) .EQ. -9) GO TO 510
JX = IROUT(JX, 3).
GO TO 500
510 IROUT(I00(19A), 3) = KSAV.
IROUT(KX, 2) = I00(A).
520 IF (IROUT(KK, 3) .EQ. -9) GO TO 530
JX = IROUT(KK, 3).
GO TO 500
530 KX = IROUT(KK, 3).
GO TO 540
540 IF (IROUT(KK, 3) .EQ. -9) GO TO 550
KX = IROUT(KK, 3).
GO TO 500
550 TLOAD(I00(19A), 1) = TLOAD(I00(19A), 1) + TLOAD(I00(19A), 1)
TLOAD(KK, 1) = TLOAD(KK, 1) + TLOAD(KK, 1).
XFILE(KK, 1) = XFILE(KK, 1) + XFILE(KK, 1).
XFILE(JX, 1) = XFILE(JX, 1) + XFILE(JX, 1).
IROUT(I00(19A), 1) = IROUT(I00(19A), 1) + IROUT(I00(19A), 1).
IROUT(KK, 1) = IROUT(KK, 1) + IROUT(KK, 1).
RTDIS(JX) = RTDIS.
RTDIS(KK) = RTDIS.
RTDIS(KK) = RTDIS.
JX = NH.
X\( X(I) \) = \( X(V) \)
X\( I(RJ) \) = \( I(RJ) \)
X\( J(V) \) = \( J(V) \)
X\( K(X) \) = \( K(X) \)
X\( L(X) \) = \( L(X) \)
X\( M(X) \) = \( M(X) \)
X\( N(X) \) = \( N(X) \)
X\( O(X) \) = \( O(X) \)
X\( P(X) \) = \( P(X) \)
X\( Q(X) \) = \( Q(X) \)
X\( R(X) \) = \( R(X) \)
X\( S(X) \) = \( S(X) \)
X\( T(X) \) = \( T(X) \)
X\( U(X) \) = \( U(X) \)
X\( V(X) \) = \( V(X) \)
X\( W(X) \) = \( W(X) \)
X\( X(I) \) = \( X(V) \)
X\( I(RJ) \) = \( I(RJ) \)
X\( J(V) \) = \( J(V) \)
X\( K(X) \) = \( K(X) \)
X\( L(X) \) = \( L(X) \)
X\( M(X) \) = \( M(X) \)
X\( N(X) \) = \( N(X) \)
X\( O(X) \) = \( O(X) \)
X\( P(X) \) = \( P(X) \)
X\( Q(X) \) = \( Q(X) \)
X\( R(X) \) = \( R(X) \)
X\( S(X) \) = \( S(X) \)
X\( T(X) \) = \( T(X) \)
X\( U(X) \) = \( U(X) \)
X\( V(X) \) = \( V(X) \)
X\( W(X) \) = \( W(X) \)
SUBROUTINE RPDRT

 THIS SUBROUTINE PROVIDES A PERIODIC PRINTOUT OF STATISTICS

 COMMON SMRM(25,191), VMRM(10,16), X(101), XM(101), XX(101), Y(101), YH(101)
 1101, YY(101), CDP(10,251), ITL(2), STZ(25,21), NSTAT, NW, NWNR, NWK
 2AD, RM, KU, DF, UF, CTU4, CTD, TUNT, NDEFO, NSFF, SMT, SHTP
 COMMON/AVK/TIM(25,25), DIS(25,25), SSAV(25,25), CMV(25,25), OFIL(1)
 12,251, NNP(2,25)
 RPN=I/IRPT
 NWK=(I-1)-RPT / T
 NWK=NWK
 DYS=I/LRT-NWK*7
 STIM=I
 SFT=NSFT
 WRITE(NWRIT,850) STIM
 850 FORMAT(1H,5X, 'SIMULATED TIME ',F5.0,/) 
 WRITE(NWRIT,870) RPN
 870 FORMAT(14X, 'REPORT PERIOD ',F5.0,/) 
 LRT=I

 C

 VEHICLE STATISTICS

 WRITE(NWRIT,1000)
 1000 FORMAT(55X, 'VEHICLE STATISTICS',/) 
 TCO=0.0
 TMC=0.0
 TCO=0.0
 TIC=0.0
 TEC=0.0
 TIN=0.0
 TAV=0.0
 TAL=0.0
 TAT=0.0
 TNG=0.0
 TNE=0.0
 TUN=0.0
 TOV=0.0

 WRITE(NWRIT,940)
 940 FORMAT(1H,5X, 'VEHICLE',1X,5X, 'TOTAL',5X, 'AVERAGE',4X, 'AVERAGE',3X, 'AVERAGE',F5.4,10D14)
 4X, 3X, 'MAINTENANCE',3X, 'MAINTENANCE',3X, 'MAINTENANCE',3X, 'MAINTENANCE',5D14)
 6X, 'COST',6X, 'COST',8X, 'COST',5X, 'COST',6D14)

 WRITE(NWRIT,950)
 950 FORMAT(1H,5X, 'TRIPS',7X, 'DAY',25X, 'PER TRIP',7X, 'LOAD')
 PD 200 J=1, NV
 VNN=NV
 AVTR=VMRM(J,4)/STIM
 IF (VMRM(J,4) .GT. 0.0) GO TO 955
 ATL=0.0
 AVL=0.0
 AGT=0.0
 GO TO 956
 955 ATL=VMRM(J,10)/VMRM(J,4)
 AVL=VMRM(J,12)/VMRM(J,4)
 AGT=VMRM(J,11)/VMRM(J,4)

 239
TADSR=0.0
TADSP=0.0
TAIR=0.0
TAIP=0.0
TXPP=0.0
TXPR=0.0
TSMR=0.0
TADMP=0.0
WRITE('WRIT,910)

910 FORMAT('STATION',8X,'TOTAL',12X,'AVERAGE',14X,'AVERAGE',15X,'AVERRF$508030
1AGE',12X,'NUMBER',7X,'NUMBER',9X,'NUMBER',12X,'TALLY$F$508040
2,16X,'ORDER',15X,'INVENTORY',10X,'INVENTORY',5X,'EXPEDITED',7X,'18X$F$508050
3,10X,'DEMAND',16X,'SIZE',18X,'LEVEL',13X,'CARRYING',6X,'ORDER$F$508060
4,14X,'DELIVERIES',13X,'CUST',14X,'REG',PREM,5X,REG,PREM,'REG,PREM$F$508070
5EM',4X,REG,PREM',6X,REG,PREM',18X,REG,PRM$F$508080
6EM',*)
DO 100 J=1,1,NSTAT
IF (SMR(J,14)+G1,0,0) GO TO 220
AOSR=0.0
GO TO 221
220 AOSR=SMR(J,15)/SMR(J,14)
221 IF (SMR(J,19)-G1,0,0) GO TO 222
AOSP=0.0
GO TO 225
222 AOSP=SMR(J,16)/SMR(J,19)
225 AIR=SMR(J,10)/STIM
AIP=SMR(J,11)/STIM
TADM=TADM+SMR(J,18)
TADMP=TADMP+SMR(J,18)
TSOL=TADMK*TADMP
SMR(J,17)=SMR(J,17)/STIM
SMR(J,18)=SMR(J,18)/STIM
STIC=TIC+TIC
TNUR=TNUR+SMR(J,14)
TNDP=TNDP+SMR(J,14)
TADS=TADS+SMR(J,15)
TAIR=TAIR+SMR(J,18)
TAIP=TAIP+SMR(J,11)
TSMR=TXPR+SMR(J,12)
TXPP=TXPP+SMR(J,13)
WRITE('WRIT,920,J,SMR(J,14),SMR(J,19),SMR(J,17),SMR(J,18),SMR(J,12),SMR(J,13)$F$508360
1,L,AOSR,AOSP,AIN,AIN,STIC,SMR(J,12),SMR(J,13)$F$508370
920 FORMAT('12X,13X,14X,15X,16X,17X,18X,19X,1AX,$F$508380
L1,12X,F9.1,5X,F9.2,4X,F4.0,3X,F4.01
C C
C STATISTICS RESET
C
TUNR=0.0
SMR(J,10)=0.0
SMR(J,11)=0.0
SMR(J,12)=0.0
SMR(J,13)=0.0
SMR(J,14)=0.0
SMR(J,15)=0.0
SMR(J,16)=0.0
SMR(J,17)=0.0
SMR(J,18)=0.0
SMR(J,19)=0.0
C
C
100 CONTINUE
    STAT=4STAT
    IF (TNOR .GT. 0.0) GO TO 230
    TAOSR=0.0
    GO TO 235
230  TAOSR=TAUSR/TNOR
235  IF (TNOP .GT. 0.0) GO TO 236
    TAOSP=0.0
    GO TO 237
236  TAOSP=TAUSP/TNOP
237  TAIR=TAIR/STIM
    TAI=TAIP/STIM
    TADM=TAADM/STIM
    WRITE(*,9301)TNOR,TNOP,TAOSR,TAOSP,TAIR,TAIKFS08600
    IF(TIC,TXPR,TFP)KFS08690
930  FORMAT('TOTAL',1X,F4.0,2X,F4.0,5X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,KFS08700
1X,F9.1,2X,F9.1,5X,F9.2,4X,F4.0,3X,F4.0)
    TACST=(TPC+TIC)/TISLO
    WRITE(*,935)TAVCS,TDEFU,SHTR,SHTP
735  FORMAT('AVERAGE TOTAL COST',F8.5,' PER GALLON SOLD',/,' NUMBER',KFS08740
1 OF DEFERRED ORDERS',15,/, 'LOST SALES REGULAR',F8.1,' GALLONS',/,' KFS08750
2 OF LOST SALES PREMIUM',F8.1,' GALLONS')
    NDEFU=0
    SHTR=0.0
    SHTP=0.0
    RETURN
END
THE DESIGN OF A RENewed PRODUCTS DISTRIBUTION SYSTEM

by

KARL FRANKLIN STROUP

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The design of a distribution system for refined petroleum products is researched by simulation. Actual data provided by a major petroleum company is used in describing a hypothesized system. This data includes historical sales data for regular and premium gasoline sales at twenty-five service stations, and costs pertinent to the operation of a fleet of delivery vehicles. As the daily demand patterns dictate the system requirements, the demand patterns for various service stations are modeled by a set of eight models, one for each product at each of four different site types. The demand models are time series models developed through the use of harmonic analysis.

As the operational costs are incomplete, statistics are monitored on other indicators which reflect the efficiency of the operation of the system. Given the established demand patterns and fixed system characteristics, parameters governing the logistics of product supply are examined through case study to determine the most effective set of operation procedures. These parameters include reorder level at the stations, order quantities, and vehicle characteristics (number of vehicles, size of compartments, shift lengths, and allowable overtime). Two modes of operation are examined, the use of vehicles divided into two compartments, and non-compartmentalized vehicles.

The most efficient operating procedure of the alternatives examined appears to be the use of compartmentalized vehicles with compartment size ratios closely approximating the ratio of regular gasoline sales to premium gasoline sales. The best operating procedure also provides
for full vehicle loads to single stations in filling the station product demands.

The simulation case studies reveal the need for delivery planning over extended periods of time, rather than day to day operation, to facilitate the leveling of orders over the planning periods to avoid concentration of orders in peak days. Further, the need for extending the considerations of compartmentalization to include more than two compartments per vehicle is indicated, as well as reorder points set individually at the stations to account for different demand rates, both between the stations, and between the two products at the individual stations.