

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 interrelationships exist between the various functions of exploration and production, refining, and marketing than are found in most other manufacturing operations, as will be seen in the following brief discussion of petroleum operations. Because of these interrelationships, the effects 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 individual 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 straight forward. 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 maintainance 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																								
T	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	4.1																							
2	11.0	6.9																						
3	10.3	3.9	2.3																					
4	7.0	2.9	4.3	2.6																				
5	3.2	6.6	7.7	7.1	5.9																			
6	3.2	6.6	7.7	7.1	5.9	1.8																		
7	6.8	3.0	4.2	3.5	2.2	3.7	5.5																	
8	3.5	6.0	12.6	10.6	8.5	6.6	6.8	8.6																
9	7.5	3.3	3.8	2.7	0.5	5.0	6.9	1.4	9.5															
10	2.0	6.0	10.3	9.7	8.4	2.6	1.4	6.3	5.3	7.6														
11	7.0	5.1	4.3	6.6	4.3	3.7	5.5	2.3	8.9	3.8	6.3													
12	6.0	7.5	15.0	12.5	10.3	9.0	9.4	10.9	2.4	11.0	7.8	10.8												
13	5.6	1.9	8.8	6.9	4.9	8.5	9.3	4.9	4.3	5.3	8.0	7.2	5.7											
14	7.7	4.0	9.0	6.9	4.9	10.6	11.1	7.2	4.9	7.5	10.3	9.3	3.5	2.1										
15	7.7	4.0	11.0	8.9	6.9	10.6	11.6	7.2	4.9	7.5	10.3	9.3	3.5	2.1	2.0									
16	9.2	5.1	4.0	1.9	3.9	8.0	11.6	6.0	10.9	4.4	10.9	8.3	12.9	7.0	7.3									
17	3.3	3.0	8.0	5.9	3.7	3.7	5.6	4.0	4.6	4.3	5.0	4.7	6.1	3.3	5.5	5.9								
18	2.7	1.5	8.3	6.5	4.3	5.3	7.2	4.5	4.3	5.0	4.7	4.6	6.1	3.3	5.5	5.9	1.6							
19	9.7	5.9	7.2	4.9	6.8	11.4	13.2	9.2	7.0	7.6	12.2	11.4	7.5	4.3	2.0	4.1	5.1	7.6						
20	9.3	5.5	8.7	6.5	6.4	12.2	13.5	8.6	6.6	7.2	11.7	11.0	6.0	3.7	1.6	2.6	6.7	8.6	7.4					
21	9.1	4.9	6.0	3.0	5.8	9.4	11.3	8.0	10.1	6.3	11.1	10.3	11.7	5.8	6.0	8.2	3.1	8.0	6.4	4.1				
22	3.3	4.0	10.9	5.1	7.1	6.6	8.6	7.0	1.7	7.6	5.2	7.2	4.1	2.3	4.3	8.9	2.9	2.6	6.4	5.9	7.8			
23	3.7	2.6	9.4	7.4	5.5	6.3	8.0	5.6	3.1	6.0	5.5	5.7	5.2	2.4	4.5	4.6	6.9	2.6	1.0	6.6	6.5	1.4		
24	7.2	3.1	6.2	4.0	3.9	9.7	10.7	6.0	6.3	4.5	9.2	8.3	8.7	2.9	3.0	5.0	4.2	6.1	4.5	3.1	2.6	3.0	4.9	3.6
25	5.5	1.3	6.3	4.1	2.1	7.9	9.7	4.2	6.6	2.7	10.2	6.4	8.3	2.7	2.7	4.8	4.3	4.3	2.8	4.9	4.3	4.2	3.4	1.8

RATE MATRIX																								
T	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	20.0																							
2	20.0	25.0																						
3	20.0	20.0	25.0																					
4	20.0	20.0	20.0	25.0																				
5	30.0	25.0	30.0	35.0	35.0																			
6	30.0	25.0	30.0	35.0	35.0	40.0																		
7	35.0	25.0	30.0	35.0	35.0	40.0	40.0																	
8	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0																
9	20.0	20.0	25.0	25.0	20.0	20.0	20.0	20.0	20.0	20.0														
10	30.0	25.0	30.0	25.0	30.0	30.0	35.0	20.0	30.0	30.0	30.0													
11	30.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0												
12	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0											
13	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0										
14	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0									
15	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0								
16	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0							
17	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0						
18	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0					
19	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0				
20	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0			
21	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0		
22	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
23	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
24	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
25	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0

TABLE 1.1

		TIME MATRIX																							
T		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	0.3																								
2	0.6	0.3																							
3	0.6	0.2	0.1																						
4	0.4	C.2	C.3																						
5	0.2	C.3	0.3	0.2																					
6	0.2	0.4	0.4	0.3	0.1																				
7	0.2	C.2	C.1	0.1	0.1	0.2																			
8	0.4	C.4	0.7	C.6	0.5	0.4	0.2																		
9	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.5	C.5															
10	0.1	C.3	0.4	C.4	0.4	0.1	0.1	C.1	0.5	C.2	C.3														
11	0.3	0.3	0.2	C.3	0.2	0.2	0.2	0.6	0.3	C.6	0.3	C.4													
12	0.3	0.4	0.8	C.7	0.5	0.5	0.5	0.6	0.3	C.6	C.5	0.4	0.3	0.2											
13	0.3	C.1	0.5	C.4	0.3	0.5	0.3	0.4	0.3	C.3	C.5	0.6	0.5	0.3	0.2										
14	0.4	C.2	0.5	C.4	0.3	0.6	0.6	0.4	0.3	C.4	C.6	0.5	0.2	0.2	0.1	0.4	C.5								
15	0.4	C.3	0.6	C.5	0.4	0.6	0.6	0.4	0.3	C.2	C.6	0.3	0.7	0.4	0.4	C.4	0.3	0.1							
16	0.5	0.3	0.2	C.1	0.2	0.3	0.4	0.2	0.6	C.2	C.6	0.3	0.7	0.4	0.4	C.4	0.3	0.3	0.4						
17	0.2	C.2	0.5	C.3	0.2	0.2	0.3	0.3	0.3	C.3	C.3	0.3	0.4	0.4	0.2	0.3	0.3	0.4	0.1	0.4					
18	0.2	0.1	0.5	C.4	0.3	0.3	C.4	C.3	C.3	C.3	C.3	0.3	0.4	0.3	0.1	0.2	0.3	0.5	0.4	0.4	0.1				
19	0.5	0.3	0.4	C.3	0.4	0.5	0.6	C.5	0.4	C.4	C.7	0.6	0.4	0.4	0.2	0.1	0.2	0.4	0.5	0.4	0.1	0.4			
20	0.5	0.3	0.5	C.4	0.4	0.5	0.6	0.5	0.4	C.4	0.6	0.6	0.6	0.4	0.3	0.3	0.5	0.2	0.4	0.2	0.3	0.4	0.4		
21	0.5	0.3	0.3	C.2	0.2	0.3	0.3	C.2	0.6	C.2	0.3	0.3	0.6	0.3	0.3	0.5	0.2	0.4	0.4	0.2	0.3	0.3	0.4	0.4	
22	0.2	0.2	0.6	C.5	0.4	0.4	0.5	0.4	C.1	C.4	C.3	C.4	0.3	0.3	0.2	0.3	C.3	0.5	0.2	0.1	0.4	0.3	0.4	0.4	
23	0.2	0.2	0.5	0.4	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	C.3	0.2	0.2	0.1	0.4	0.3	0.4	0.4	
24	0.4	C.2	0.4	C.2	0.2	0.4	0.5	0.3	0.4	C.3	C.5	0.5	0.5	0.2	0.2	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.3	0.2	0.1
25	0.3	0.1	0.4	C.3	0.2	0.4	0.4	0.3	0.4	C.2	C.6	0.4	0.5	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.1

TABLE 1.1 (continued)

STATION NUMBER	TYPE	STORAGE TANK CAPACITIES	
		REGULAR	PREMIUM
1	Residential	8000	4000
2	Residential	6000	4000
3	Interstate	12000	6000
4	Shopping Center	8000	4000
5	Interstate	8000	6000
6	Interstate	8000	6000
7	Interstate	12000	6000
8	Business	6000	6000
9	Shopping Center	8000	6000
10	Business	8000	6000
11	Residential	8000	6000
12	Residential	8000	6000
13	Business	8000	6000
14	Residential	8000	4000
15	Shopping Center	8000	4000
16	Residential	6000	4000
17	Shopping Center	8000	4000
18	Shopping Center	6000	4000
19	Residential	6000	4000
20	Residential	6000	6000
21	Interstate	12000	6000
22	Business	6000	6000
23	Business	8000	6000
24	Business	6000	4000
25	Shopping Center	8000	4000

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 effect 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 expressable 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:

$$\begin{aligned} \xi = & C + A_1 \sin \frac{2\pi t}{P} + A_2 \sin \frac{4\pi t}{P} + \dots + A_k \sin \frac{2k\pi t}{P} + \dots \\ & + B_1 \cos \frac{2\pi t}{P} + B_2 \cos \frac{4\pi t}{P} + \dots + B_k \cos \frac{2k\pi t}{P} + \dots \end{aligned}$$

(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 α , where, for a given pair of periodic terms, $\alpha = \arctan B_i/A_i$, and the amplitude of the effect is expressed as $a = \sqrt{A_i^2 + B_i^2}$ (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

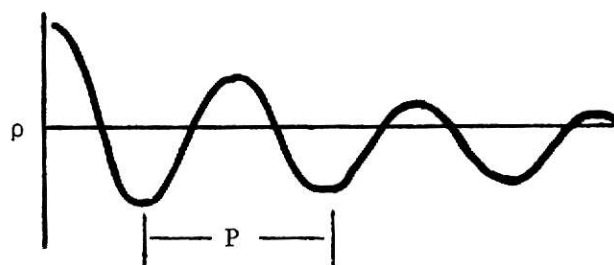
$$\rho_{xx}(k) = \frac{\gamma_{xx}(t, t+k)}{\sigma_x(t) \sigma_x(t+k)}$$

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 prepared. 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 π/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:



where P is the period. Note that $2\pi/P = \omega$, the frequency, and ω can also be determined from the abscissa 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 abscissa.

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:

$$P(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \gamma_{xx}(t) \cos \omega t \, dt$$

(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):

$$\text{upper control limit} = \bar{s} + \ln \left(\frac{v}{\chi_v^2 (1 - \alpha/2)} \right)$$

$$\text{lower control limit} = \bar{s} + \ln \left(\frac{v}{\chi_v^2 (\alpha/2)} \right)$$

where v = degrees of freedom

$$v = \frac{2Mb'}{m}$$

m = number of lags considered

M = number of observations

b' = constant for Tukey Hanning window

$$= 1.33$$

α = significance level

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

$\chi^2_v(\alpha/2)$ = 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:

$$m = \text{number of lags} = 200$$

$$M = \text{number of observations} = 735$$

$$b' = \text{window constant} = 1.33$$

bandwidth

$$b = b'/m = \frac{1.33}{200} = .00665$$

degrees of freedom

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

control limits

$$\left. \begin{array}{l} \chi_{10}^2 (.05/2) = 20.483 \\ \chi_{10}^2 (.975) = 3.247 \end{array} \right\} \text{From Chi-square table (7,22)}$$

$$LCL = \bar{s} + \ln \left(\frac{10}{20.483} \right) = \bar{s} + \ln(.489) = \bar{s} - .7154$$

$$UCL = \bar{s} + \ln \left(\frac{10}{3.247} \right) = \bar{s} + \ln (3.08) = \bar{s} + 1.1249$$

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:

t	X_m	X_t	X_w	X_{th}	X_f	X_s
1	1	0	0	0	0	0
2	0	1	0	0	0	0
3	0	0	1	0	0	0
4	0	0	0	1	0	0
5	0	0	0	0	1	0
6	0	0	0	0	0	1
7	0	0	0	0	0	0
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
735	0	0	0	0	0	0

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 $2\pi t/182.5$ 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 explanative 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:

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

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 deceptively 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)

STATION NUMBER	SITE* TYPE	1967		1968		1967		1968		1967		1968	
		MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.
1	R	799	93	881	114	514	63	547	73				
2	R	498	57	547	69	311	44	329	48				
3	I	1022	120	1189	136	668	84	762	97				
4	S	292	61	373	46	221	43	282	40				
5	I	904	97	1048	109	609	66	695	77				
6	I	613	82	733	86	405	59	486	66				
7	I	1107	126	1288	144	726	87	823	105				
8	B	627	78	691	97	404	62	426	68				
9	S	239	58	289	48	158	36	185	32				
10	B	448	50	517	64	295	39	343	46				
11	R	307	40	340	48	197	27	210	31				
12	R	197	25	216	29	124	19	131	19				
13	B	451	50	527	66	297	37	348	44				
14	R	685	82	756	93	475	66	502	72				
15	S	105	35	130	29	69	20	83	21				
16	R	397	48	436	57	255	36	270	37				
17	S	175	48	211	38	108	29	125	30				
18	S	283	75	347	62	171	42	200	45				
19	R	662	77	757	94	436	56	499	65				
20	R	706	84	813	106	442	63	468	68				
21	I	1183	135	1368	148	771	99	873	111				
22	B	638	71	728	90	455	59	510	70				
23	B	945	105	1070	132	695	86	770	102				
24	B	701	77	806	100	455	59	515	70				
25	S	283	72	344	58	189	52	218	48				

*R - RESIDENTIAL SITE
I - INTERSTATE SITE

S - SHOPPING CENTER SITE
B - BUSINESS DISTRICT SITE

TABLE 2.1

CORRELATION BETWEEN REGULAR AND PREMIUM GASOLINE SALES

<u>STATION NUMBER</u>	<u>SITE TYPE</u>	<u>CORRELATION COEFFICIENT</u>
1	Residential	.493
2	Residential	.395
3	Interstate	.674
4	Shopping Center	.830
5	Interstate	.704
6	Interstate	.707
7	Interstate	.656
8	Business	.453
9	Shopping Center	.571
10	Business	.669
11	Residential	.377
12	Residential	.343
13	Business	.685
14	Residential	.410
15	Shopping Center	.350
16	Residential	.369
17	Shopping Center	.357
18	Shopping Center	.384
19	Residential	.585
20	Residential	.402
21	Interstate	.653
22	Business	.591
23	Business	.569
24	Business	.633
25	Shopping Center	.500

TABLE 2.2

RESULTS WITH DAY FACTOR - HARMONIC MODEL WITH LINEAR TREND

REGULAR GASOLINE SALES

INTERSTATE SITES

	STATION 3			STATION 6			STATION 21		
R	.8098			.8415			.8055		
S.E.E.	91.0039			56.3917			101.6094		
CONSTANT	1010.9715			616.1470			1156.0957		
LINEAR TREND	COEFF.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	
SINE $2\pi t/365$	0.4818	27.4818	0.3452	0.0109	31.7713	0.5329	0.0196	27.2263	
COSINE $2\pi t/365$	-37.5195	-7.2450	-19.0452	3.2090	-5.9349	-45.6771	5.7822	-7.8996	
SINE $2\pi t/182.5$	-26.6569	-5.6322	-16.5274	2.5382	-5.6353	-30.1788	5.2846	-5.7107	
COSINE $2\pi t/182.5$	10.9844	2.2561	5.1252	3.0170	1.6988	13.7805	5.4361	2.5350	
MONDAY	32.3719	6.8392	16.5667	2.9330	5.6483	32.6870	5.2849	6.1850	
TUESDAY	-110.6668	-8.8109	-86.7180	7.7831	-11.1419	-92.3807	14.0240	-6.5873	
WEDNESDAY	-115.0228	-9.1578	-95.0240	7.7830	-12.2092	-107.9495	14.0238	-7.6976	
THURSDAY	-114.5882	-9.1233	-98.4251	7.7829	-12.6463	-117.0610	14.0237	-8.3474	
FRIDAY	-90.0105	-7.1665	-83.0642	7.7829	-10.6727	-77.0579	14.0236	-5.4949	
SATURDAY	-108.6422	-8.6500	-88.9318	7.7828	-11.4267	-103.6357	14.0235	-7.3901	
SUNDAY	-56.0926	-4.4661	-50.4088	7.7828	-6.4770	-55.0989	14.0234	-3.9291	

TABLE 2.3

RESULTS WITH DAY - FACTOR HARMONIC MODEL

REGULAR GASOLINE SALES

BUSINESS SITES

	STATION 10			STATION 23		
R				0.6965		
S.E.E.				97.0433		
CONSTANT				893.5401		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
LINEAR TREND	0.1997	0.0085	23.4187	0.3675	0.0183	20.0942
SINE $2\pi t/365$	-12.8172	2.5660	-4.9950	-27.9164	5.5041	-5.0720
COSINE $2\pi t/365$	- 4.9480	2.3529	-2.1029	-11.8716	5.0470	-2.3522
SINE $2\pi t/182.5$	0.00	-	-	0.00	-	-
COSINE $2\pi t/182.5$	11.8319	2.3531	5.0283	25.0538	5.0473	4.9638
MONDAY	-21.0220	6.2442	-3.3666	0.0	-	-
TUESDAY	-46.3630	6.2441	-7.4250	-58.6695	10.5884	-5.5409
WEDNESDAY	-42.9134	6.2441	-6.8726	-56.5477	10.5883	-5.3406
THURSDAY	-23.8733	6.2440	-3.8234	0.0	-	-
FRIDAY	-38.2521	6.2440	-6.1262	-43.8751	10.5883	-4.1437
SATURDAY	-12.2880	6.2440	-1.9680	0.0	-	-

TABLE 2.4

RESULTS WITH DAY FACTOR - HARMONIC MODEL

REGULAR GASOLINE

RESIDENTIAL SITES

	STATION 1			STATION 11		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
R						
S.E.E.						
CONSTANT						
LINEAR TREND	0.2451	0.0170	14.3751	0.0973	0.0073	13.3780
SINE $2\pi t/365$	-26.9417	5.1308	-5.2510	-10.3782	2.1899	-4.7390
COSINE $2\pi t/365$	- 8.5216	4.7047	-1.8113	- 5.2281	2.0081	-2.6035
SINE $2\pi t/182.5$	0.0	-	-	0.0	-	-
COSINE $2\pi t/182.5$	22.3976	4.7050	4.7604	8.9744	2.0082	4.4688
MONDAY	0.0	-	-	0.0	-	-
TUESDAY	-37.0180	9.8703	-3.7505	-19.4911	4.2129	-4.6266
WEDNESDAY	-31.0692	9.8702	-3.1478	-10.7967	4.2129	-2.5628
THURSDAY	0.0	-	-	0.0	-	-
FRIDAY	-23.7520	9.8702	-2.4064	- 9.7219	4.2128	-2.3077
SATURDAY	0.0	-	-	0.0	-	-

TABLE 2.5

RESULTS WITH DAY FACTOR - HARMONIC MODEL

REGULAR GASOLINE SALES

SHOPPING CENTER SITES

	STATION 4			STATION 15		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
R	0.2257	0.0063	35.6891	0.069	.0055	12.4644
S.E.E.	-15.1467	1.8680	- 8.1083	- 8.9309	1.6347	- 5.4633
CONSTANT	-11.9941	1.7073	- 7.0253	- 7.4150	1.4940	- 4.9631
LINEAR TREND	8.1697	1.7562	4.6518	4.3093	1.5369	2.8040
SINE $2\pi t/365$	9.2195	1.7074	5.3998	5.1204	1.4941	3.4270
COSINE $2\pi t/365$	-77.5983	4.5307	-17.1273	- 6.5335	3.0281	- 2.1576
SINE $2\pi t/182.5$	-58.5098	4.5306	-12.9143	0.00	-	-
COSINE $2\pi t/182.5$	-68.1927	4.5306	-15.0516	0.00	-	-
MONDAY	-67.2851	4.5306	-14.8514	0.00	-	-
TUESDAY	-65.6251	4.5305	-14.4850	0.00	-	-
WEDNESDAY	-45.6316	4.5305	-10.0720	0.00	-	-
THURSDAY						
FRIDAY						
SATURDAY						

TABLE 2.6

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

REGULAR GASOLINE SALES

INTERSTATE SITES

	STATION 5			STATION 7		
	COEFF	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
R						
S.E.E.						
CONSTANT						
LINEAR TREND						
$t^2/10000$	0.2219	0.0494	4.4969	.223	.0681	3.2775
SINE $2\pi t/365$	2.5392	0.6461	3.9301	3.9385	0.8919	4.4160
COSINE $2\pi t/365$	-33.1948	3.8705	-8.5764	-42.7233	5.3429	-7.9963
SINE $2\pi t/182.5$	-25.5778	3.6545	-6.9991	-31.9692	5.0447	-6.3372
COSINE $2\pi t/182.5$	8.4758	3.6357	2.3313	12.1100	5.0189	2.4129
SINE $2\pi t/9125$	22.8381	3.5449	6.4425	26.7096	4.8934	5.4582
COSINE $2\pi t/91.25$	-10.3505	3.5739	-2.8962	-14.7326	4.9335	-2.9863
SINE $2\pi t/60.83$	0.0	-	-	0.0	-	-
COSINE $2\pi t/60.83$	0.0	-	-	0.0	-	-
SINE $2\pi t/45.625$	6.0163	3.5371	1.7009	11.337	4.8827	2.3212
COSINE $2\pi t/45.625$	-7.9476	3.5555	-2.2353	-9.8999	4.9081	-2.0171
SINE $2\pi t/45.625$	0.0	-	-	0.0	-	-
COSINE $2\pi t/45.625$	6.7654	3.5488	1.9064	9.6884	4.8988	1.9777
SINE $2\pi t/30.416$	9.0649	3.5422	2.5591	11.3210	4.8898	2.3152
COSINE $2\pi t/30.416$	-84.3406	9.3764	-8.9950	-99.7561	12.9434	-7.7078
MONDAY	-92.3706	9.3763	-9.8515	-107.2697	12.9432	-8.2877
TUESDAY	-97.6647	9.3762	-10.4152	-120.3322	12.9430	-9.2971
WEDNESDAY	-69.9452	9.3761	-7.4600	-76.9430	12.9429	-5.9448
THURSDAY	-89.5185	9.3760	-9.5476	-104.0165	12.9428	-8.0366
FRIDAY	-49.8033	9.3760	-5.3118	-66.4099	12.9428	-5.1310
SATURDAY						

TABLE 2.7

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

REGULAR GASOLINE SALES

RESIDENTIAL SITES

	STATION 12				STATION 14				STATION 16			
R												
S.E.E.												
CONSTANT												
LINEAR TREND	COEFF.	S.D.	T VALUE	COEFF.	COEFF.	S.D.	T VALUE	COEFF.	COEFF.	S.D.	T VALUE	
$t/100.00$	-0.0588	0.0175	-3.3502	-0.1701	0.0541	0.0327	-3.1432	-0.1036	0.0327	413.7958	-3.1711	
$\sin 2\pi t/365$	1.5458	0.2304	6.7101	5.0273	0.7096	0.4295	7.0843	2.9098	0.4295		6.7907	
$\cosine 2\pi t/365$	-4.6314	1.3740	-3.3708	-18.9445	4.2372	2.5577	-4.4710	-9.7125	2.5577		-3.7974	
$\sin 2\pi t/182.5$	-3.7646	1.3029	-2.8894	-13.5501	4.0144	2.4244	-3.3754	-5.1486	2.4244		-2.1237	
$\cosine 2\pi t/182.5$	0.0			0.0				0.0				
$\sin 2\pi t/91.25$	4.4946	1.2638	3.5564	15.7971	3.8939	8.5306	4.0569	8.5306	2.3516	3.6276		
$\cosine 2\pi t/91.25$	0.0			-8.9042	3.9250		-2.2686	0.0				
$\sin 2\pi t/60.83$	-4.0991	1.2609	-3.2510	0.0				-4.9146	2.3623	-2.0805		
$\cosine 2\pi t/60.83$	0.0			0.0				0.0				
$\sin 2\pi t/45.625$	3.0016	1.2629	2.3768	11.6075	3.8853		2.9875	-6.9621	2.3586	-2.9518		
$\cosine 2\pi t/45.625$	0.0			-10.2434	3.9056		-2.6228	0.0				
$\sin 2\pi t/30.416$	0.0			0.0				4.5875	2.3542	1.9486		
$\cosine 2\pi t/30.416$	0.0			7.7794	3.8983		1.9956	5.7970	2.3498	2.4670		
MONDAY	0.0			0.0				0.0				
TUESDAY	-10.7124	2.6428	-4.0534	14.1718	8.4099		1.6851	-32.3372	5.0788	-6.3671		
WEDNESDAY	-11.9557	2.6428	-4.5239	-14.6680	8.4098		-1.7422	-23.3157	5.0787	-4.5909		
THURSDAY	0.0			-20.5647	8.4097		-2.4454	-9.5396	5.0787	-1.8823		
FRIDAY	-5.3172	2.6428	-2.0120	20.8629	8.4096		2.4808	-22.2689	5.0787	-4.3848		
SATURDAY	0.0			0.0								

TABLE 2.9

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

REGULAR GASOLINE SALES

RESIDENTIAL SITES

	STATION 19			STATION 20		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
R						
S.E.E.						
CONSTANT						
LINEAR TREND						
$t^2/10000$	-0.0965	0.0486	-1.9843	-0.1088	0.0548	-1.9860
SINE $2\pi t/365$	5.0153	0.6376	7.8659	5.5485	0.7186	7.7217
COSINE $2\pi t/365$	-18.8856	3.8076	-4.9599	-23.8787	4.2882	-5.5685
SINE $2\pi t/182.5$	-15.0078	3.6076	-4.1601	-15.6321	4.0625	-3.8479
COSINE $2\pi t/182.5$	0.0	-	-	0.0	-	-
COSINE $2\pi t/182.5$	14.3307	3.4992	4.0954	-13.6399	3.9409	3.4611
SINE $2\pi t/91.25$	-11.0652	3.5273	-3.1370	-7.3721	3.9721	-1.8560
COSINE $2\pi t/91.25$	0.0	-	-	-9.1691	3.9318	-2.3320
SINE $2\pi t/60.83$	0.0	-	-	0.0	-	-
COSINE $2\pi t/60.83$	0.0	-	-	7.7167	3.9323	1.9624
SINE $2\pi t/45.625$	-6.2158	3.5098	-1.7710	-10.3874	3.9524	-2.6281
COSINE $2\pi t/45.625$	0.0	-	-	0.0	-	-
SINE $2\pi t/30.416$	0.0	-	-	7.2638	3.9451	1.8412
COSINE $2\pi t/30.416$	9.4102	3.4967	2.6912	10.6775	3.9379	2.7115
MONDAY	0.0	-	-	0.0	-	-
TUESDAY	-37.5256	7.3176	-5.1281	-34.8872	8.2402	-4.2338
WEDNESDAY	-36.1125	7.3175	-4.9351	-35.6120	8.2401	-4.3218
THURSDAY	0.0	-	-	0.0	-	-
FRIDAY	-30.2159	7.3175	-4.1293	-32.1492	8.2401	-3.9016
SATURDAY	0.0	-	-	0.0	-	-

Table 2.9 (Cont.)

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

REGULAR GASOLINE SALES

SHOPPING CENTER SITES

	STATION 9				STATION 17				STATION 18			
R	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
S.E.E.												
CONSTANT	0.3189	0.0297	10.7239	0.2693	0.0268	10.0347	0.3886	0.0412	9.4376	0.6681	0.0412	16.1228
LINEAR TREND	-2.4465	0.3893	-6.2839	-2.2886	0.3516	-6.5092	-2.8508	0.5394	-5.2848	56.7191	0.5394	105.2848
$t^2/10000$	-15.3604	2.3317	-6.5877	-11.8029	2.1036	-5.6109	-20.1129	3.2280	-6.2307	227.9920	3.2280	736.2307
COSINE $2\pi t/365$	-9.1445	2.2019	-4.1530	-6.0380	1.9882	-3.0370	-15.1096	3.0510	-4.9524		3.0510	14.9524
SINE $2\pi t/182.5$	6.9098	2.1906	3.1543	8.1574	1.9775	4.1251	10.9546	3.0346	3.6099		3.0346	10.9546
COSINE $2\pi t/182.5$	10.2954	2.1358	4.8203	5.7629	1.9285	2.9882	17.1943	2.9594	5.8101		2.9594	5.8101
SINE $2\pi t/91.25$	-4.7594	2.1534	-2.2102	0.0	1.9241	3.0081	0.0	2.9525	2.1228		2.9525	2.1228
COSINE $2\pi t/91.25$	6.7863	2.1309	3.1847	0.0	1.9243	1.7182	0.0	6.2676	2.1228		6.2676	2.1228
SINE $2\pi t/60.83$	0.0	-	-	3.3063	-	-	0.0	0.0	-		0.0	-
COSINE $2\pi t/60.83$	0.0	-	-	0.0	-	-	0.0	0.0	-		0.0	-
SINE $2\pi t/45.625$	0.0	-	-	0.0	-	-	0.0	0.0	-		0.0	-
COSINE $2\pi t/45.625$	0.0	-	-	0.0	-	-	0.0	0.0	-		0.0	-
SINE $2\pi t/30.416$	4.0171	2.1383	1.8787	0.0	-	-	0.0	0.0	-		0.0	-
COSINE $2\pi t/30.416$	0.0	-	-	0.0	-	-	0.0	0.0	-		0.0	-
MONDAY	-57.2832	5.6496	-10.1393	-9.4130	3.9513	-2.3822	-26.6716	6.0637	-4.3986		6.0637	-4.3986
TUESDAY	-30.5598	5.6496	-5.4093	0.0	-	-	0.0	0.0	-		0.0	-
WEDNESDAY	-43.3879	5.6495	-7.6800	0.0	-	-	-12.1550	6.0636	-2.0046		6.0636	-2.0046
THURSDAY	-42.1099	5.6494	-7.4538	-10.1456	3.9512	-2.5677	0.0	0.0	-		0.0	-
FRIDAY	-36.9924	5.6494	-6.5480	0.0	-	-	0.0	0.0	-		0.0	-
SATURDAY	-16.6638	5.6494	-2.9497	0.0	-	-	0.0	0.0	-		0.0	-

TABLE 2.10

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

PREMIUM GASOLINE SALES

INTERSTATE SITES

	STATION 3			STATION 6		
R	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
S.E.E.						
CONSTANT						
LINEAR TREND	0.0	-	-	0.1087	0.0335	3.2418
$t^2/10000$	3.5067	0.1794	19.5446	1.5434	0.4374	3.5282
SINE $2\pi t/365$	-18.1091	4.0151	-4.5102	-6.6957	2.7083	-2.4723
COSINE $2\pi t/365$	-7.4902	3.7088	-2.0195	0.0	-	-
SINE $2\pi t/182.5$	15.8611	3.7925	4.1823	4.6671	2.5453	1.8336
COSINE $2\pi t/182.5$	32.2512	3.6970	8.7235	17.6817	2.4820	7.1239
SINE $2\pi t/91.25$	0.0	-	-	0.0	-	-
COSINE $2\pi t/91.25$	0.0	-	-	0.0	-	-
SINE $2\pi t/60.83$	0.0	-	-	-5.2632	2.4935	-2.1108
COSINE $2\pi t/60.83$	13.7781	3.6974	3.7265	6.7872	2.4766	2.7405
SINE $2\pi t/45.625$	0.0	-	-	0.0	-	-
COSINE $2\pi t/45.625$	7.1553	3.6991	1.9344	0.0	-	-
SINE $2\pi t/30.416$	13.8226	3.7095	3.7263	8.8380	2.4848	3.5568
COSINE $2\pi t/30.416$	7.3404	3.7030	1.9823	6.8024	2.4802	2.7427
MONDAY	-86.9273	9.8022	-8.8681	-79.5750	6.5653	-12.1205
TUESDAY	-74.0223	9.8021	-7.5517	-67.0618	6.5653	-10.2146
WEDNESDAY	-68.3222	9.8020	-6.9702	-58.3171	6.5652	-8.8828
THURSDAY	-53.2455	9.8019	-5.4322	-56.3216	6.5651	-8.5789
FRIDAY	-79.2489	9.8018	-8.0851	-65.7321	6.5651	-10.0124
SATURDAY	-47.5227	9.8018	-4.8484	-49.5011	6.5651	-7.5401

TABLE 2.11

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND
PREMIUM GASOLINE SALES

BUSINESS SITES

	STATION 8			STATION 10			STATION 23		
R	COEFF.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	
S.E.E.									
CONSTANT	444.0705	0.0411	0.0	33.9809	20.7160	0.0	698.9010	14.0809	
LINEAR TREND	-0.1307	-3.1825	0.0	307.7311	-3.4855	0.0	0.6252	-3.6790	
t ² /10000	2.6561	4.9358	1.7779		1.9210	2.8455	80.0147	3.0256	
SINE 2-t/365	-12.7349	-3.9541	-6.6957		1.7745	-16.6414		3.4770	
COSINE 2-t/365	5.8753	1.9302	4.8515		1.8145	12.6421		8.6213	
SINE 2-t/182.5	10.6853	3.5294	3.9550		1.7688	14.8559		-	
COSINE 2-t/182.5	18.8452	6.3826	13.3605		-	35.9079		-	
SINE 2-t/91.25	0.0	-	0.0		-	0.0		-	
COSINE 2-t/91.25	0.0	-	0.0		-	0.0		-	
SINE 2-t/60.83	0.0	-	0.0		-	0.0		-	
COSINE 2-t/60.83	11.7125	3.975e	5.4732		3.0940	15.8048		3.7943	
SINE 2-t/45.625	7.6329	2.5823	0.0		-	0.0		-	
COSINE 2-t/45.625	6.7329	2.2820	0.0		-	0.0		-	
SINE 2-t/30.416	0.0	-	5.9428		1.7748	12.5307		2.9984	
COSINE 2-t/30.416	0.0	-	4.7423		1.7717	10.3165		2.4729	
MONDAY	-47.8238	-7.0707	-31.4252		4.6900	-36.3993		-4.0368	
TUESDAY	-41.1074	-6.0778	-27.8963		4.6349	-30.4249		-3.3742	
WEDNESDAY	-38.5308	-5.6969	-25.8131		4.6899	-24.5599		-2.7238	
THURSDAY	-27.6557	-4.0890	-17.3182		4.6899	0.0		-	
FRIDAY	-46.9677	-6.9445	-31.4209		4.6898	-33.7757		-3.7459	
SATURDAY	0.0	-	0.0		-	0.0		-	

TABLE C.12

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

PREMIUM GASOLINE SALES

RESIDENTIAL SITES

	STATION 1			STATION 2			STATION 19		
R	.5297			-.4934			-.6693		
S.E.E.	60.5948			41.2314			51.1972		
CONSTANT	524.9864			317.6504			437.9178		
	COEFF. S.D.			COEFF. S.D.			COEFF. S.D.		T VALUE
LINEAR TREND	0.0440			0.0299			-		-
$t^2/10000$	-0.1600			-0.0919			0.1293		17.9776
SINE $2\pi t/365$	3.4089			1.9242			2.3245		-3.5605
COSINE $2\pi t/365$	-11.3947			-6.8130			-10.3049		1.7739
SINE $2\pi t/182.5$	6.2727			5.0698			4.7425		3.2290
COSINE $2\pi t/182.5$	10.0465			8.6402			8.8275		7.6972
SINE $2\pi t/91.25$	26.0313			17.1299			20.5128		-
COSINE $2\pi t/91.25$	0.0			0.0			0.0		-
SINE $2\pi t/60.83$	0.0			0.0			0.0		-
COSINE $2\pi t/60.83$	11.2270			-3.7492			0.0		-
SINE $2\pi t/45.625$	0.0			7.2153			2.6652		2.9907
COSINE $2\pi t/45.625$	0.0			4.2388			0.0		-
SINE $2\pi t/30.416$	9.6504			0.0			0.0		-
COSINE $2\pi t/30.416$	9.0011			6.4092			5.8512		2.1882
MONDAY	0.0			3.8345			7.7340		2.8974
TUESDAY	0.0			0.0			-23.8325		-3.8946
WEDNESDAY	0.0			0.0			6.1194		-3.3074
THURSDAY	18.0998			0.0			-20.2389		-2.2014
FRIDAY	0.0			10.6118			-13.4708		-
SATURDAY	0.0			0.0			0.0		-
	6.3672			4.3462			-21.1061		-3.4491
	-			-			6.1192		-1.6536
	-			-			6.1192		-
	-			-			-10.1190		-

TABLE 2.13

RESULTS WITH EXPANDED DAY FACTOR - HARMONIC MODEL WITH QUADRATIC TREND

PREMIUM GASOLINE SALES

SHOPPING CENTER SITES

	STATION 9			STATION 17			STATION 25		
R	COEFF.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE	
S.E.E.	0.6164	13.6104	0.0535	0.0050	10.8033	0.0879	0.0084	10.4591	
CONSTANT	163.3930					0.0			
LINEAR TREND	0.0762					0.0			
$t^2/10000$	0.0		0.0			0.0			
SINE $2\pi t/365$	-5.0778	-3.0713	0.0			-7.5067	2.4804	-3.0265	
COSINE $2\pi t/365$	-9.0503	-5.9892	-6.6140	1.4509	-4.5586	-11.1455	2.2671	-4.9162	
SINE $2\pi t/182.5$	3.3078	2.1282	4.6398	1.4875	3.1141	6.0955	2.3318	2.6141	
COSINE $2\pi t/182.5$	7.1308	4.7187	6.1522	1.4510	4.2401	7.5613	2.2672	3.3350	
SINE $2\pi t/91.25$	0.0		0.0			0.0			
COSINE $2\pi t/91.25$	0.0		3.9699	1.4513	2.7354	4.7653	2.2678	2.1013	
SINE $2\pi t/60.83$	0.0		-2.9597	1.4617	-2.0248	0.0			
COSINE $2\pi t/60.83$	3.1321	2.0713	0.0			4.4629	2.2686	1.9673	
SINE $2\pi t/45.625$	0.0		0.0			0.0			
COSINE $2\pi t/45.625$	0.0		0.0			0.0			
SINE $2\pi t/30.416$	0.0		2.5193	1.4570	1.7291	0.0			
COSINE $2\pi t/30.416$	3.3156	2.1862	0.0			4.4725	2.2722	1.9683	
MONDAY	-35.3530	-8.8170	-7.2607	2.9821	-2.4347	-54.1670	6.0152	-9.0050	
TUESDAY	-25.3716	-6.3277	0.0			-39.9878	6.0151	-6.6479	
WEDNESDAY	-25.3413	-6.3202	0.0			-45.0353	6.0151	-7.4871	
THURSDAY	-23.0527	-5.7495	0.0			-39.4239	6.0150	-6.5543	
FRIDAY	-25.4868	-6.3566	0.0			-44.7252	6.0150	-7.4356	
SATURDAY	-10.6523	-2.6570	-5.6322	2.9821	-1.8887	-22.1775	6.0150	-3.6871	

TABLE 2.14

RESULTS WITH COMBINED MODEL

INTERSTATE SITES

	REGULAR	PREMIUM	
R	.9441	.9071	
S.E.E.	84.4814	69.3124	
CONST.	1039.1212	694.3389	
	COEFF. S.D.	COEFF. S.D.	T VALUE
LINEAR TREND	0.0275	0.0436	1.9364
$t^2/10000$	0.3609	2.8608	9.6977
SINE $2\pi t/365$	2.1549	-14.6595	-8.2974
COSINE $2\pi t/365$	2.0344	-6.2632	-3.7560
SINE $2\pi t/182.5$	2.0227	12.3948	7.4707
COSINE $2\pi t/182.5$	1.9754	31.0738	19.2095
SINE $2\pi t/91.25$	1.9880	-0.0525	-0.0322
COSINE $2\pi t/91.25$	1.9712	-3.7851	-2.3453
SINE $2\pi t/60.83$	1.9811	-5.8460	-3.5976
COSINE $2\pi t/60.83$	1.9714	11.0057	6.8184
SINE $2\pi t/45.625$	1.9782	3.3754	2.0806
COSINE $2\pi t/45.625$	1.9719	6.4205	3.9762
SINE $2\pi t/30.416$	1.9753	11.3862	7.0315
COSINE $2\pi t/30.416$	1.9733	6.9109	4.2755
MONDAY	5.2220	-76.5474	-17.8921
TUESDAY	5.2219	-61.0379	-14.2672
WEDNESDAY	5.2219	-53.2082	-12.4372
THURSDAY	5.2218	-43.8541	-10.2508
FRIDAY	5.2243	-64.7160	-15.1273
SAURDAY	5.2243	-31.9329	-7.4643
STATION 5	4.4069	-63.7415	-17.6295
STATION 6	4.4069	-270.7796	-74.8917
STATION 7	4.4069	59.2830	16.3964
STATION 21	4.4228	106.5306	29.4640

TABLE 2.15

STATION 3 BASE LEVEL

RESULTS WITH COMBINED MODEL

BUSINESS SITES

	REGULAR			PREMIUM		
	COEFF.	S.D.	T VALUE	COEFF.	S.D.	T VALUE
R	.9448			.9360		
S.E.E.	66.2655			55.0695		
CONSTANT	643.3499			411.9199		
	COEFF.	S.D.	T VALUE	COEFF.	S.D.	T VALUE
LINEAR TREND	-0.1183	0.0197	-6.0175	-0.0484	0.0163	-2.9595
$t^2/10000$	5.0190	0.2575	19.4945	2.5729	0.2140	12.0255
SINE $2\pi t/365$	-19.8224	1.5419	-12.8557	-11.6066	1.2814	-9.0578
COSINE $2\pi t/365$	-14.6436	1.4553	-10.0622	6.3600	1.2094	5.2587
SINE $2\pi t/182.5$	0.4240	1.4480	0.2928	8.8103	1.2033	7.3216
COSINE $2\pi t/182.5$	14.4375	1.4118	10.2265	21.4938	1.1732	18.3200
SINE $2\pi t/91.25$	-8.3371	1.4232	-5.8579	-1.3297	1.1828	-1.1242
COSINE $2\pi t/91.25$	-6.2257	1.4085	-4.4200	-3.3145	1.1706	-2.8315
SINE $2\pi t/60.83$	-3.6843	1.4182	-2.5979	-3.4954	1.1785	-2.9659
COSINE $2\pi t/60.83$	5.7433	1.4087	4.0770	10.0570	1.1707	8.5907
SINE $2\pi t/45.625$	-7.9863	1.4159	-5.6405	3.0496	1.1767	2.5918
COSINE $2\pi t/45.625$	3.2609	1.4093	2.3139	2.6017	1.1712	2.2214
SINE $2\pi t/30.416$	6.8311	1.4132	4.8336	8.4883	1.1745	7.2274
COSINE $2\pi t/30.416$	8.7946	1.4107	6.2343	6.3195	1.1723	5.3904
MONDAY	-26.6120	3.7338	-7.1273	-39.8123	3.1030	-12.8304
TUESDAY	-60.3064	3.7338	-16.1516	-34.8268	3.1029	-11.2239
WEDNESDAY	-56.2744	3.7337	-15.0719	-30.7668	3.1029	-9.9156
THURSDAY	-26.1128	3.7337	-6.9938	-19.3399	3.1029	-6.2329
FRIDAY	-49.5043	3.7337	-13.2589	-38.4077	3.1028	-12.3783
SATURDAY	-9.6935	3.7336	-2.5963	-15.5557	3.1028	-5.0134
STATION 10	-176.2463	3.4567	-50.9872	-96.6585	2.8726	-33.6479
STATION 13	-170.1578	3.4567	-49.2258	-93.1850	2.8726	-32.4387
STATION 22	23.8748	3.4567	6.9069	67.5401	2.8726	23.5114
STATION 23	348.3660	3.4567	100.7805	317.5714	2.8726	110.5500
STATION 24	94.7116	3.4567	27.3996	69.5279	2.8726	24.2034
STATION 8 BASE LEVEL						

TABLE 2.16

RESULTS WITH COMBINED MODEL

RESIDENTIAL SITES

R S.E.E. CONSTANT	REGULAR GRADE			PREMIUM GRADE		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
LINEAR TREND	-0.1200	0.0166	-7.2111	-0.0872	0.0124	-7.0535
$t^2/10000$	4.0262	0.2179	18.4784	2.1102	0.1618	13.0407
SINE $2\pi t/365$	-16.3154	1.3049	-12.5028	-8.0587	0.9691	-8.3155
COSINE $2\pi t/365$	-11.3018	1.2316	-9.1762	4.8830	0.9147	5.3384
SINE $2\pi t/182.5$	0.7766	1.2254	0.6338	7.4156	0.9101	8.1482
COSINE $2\pi t/182.5$	11.7002	1.1948	9.7926	17.6099	0.8873	19.8460
SINE $2\pi t/91.25$	-7.0256	1.2045	-5.8328	-1.3402	0.8945	-1.4983
COSINE $2\pi t/91.25$	-4.7348	1.1921	-3.9719	-1.6772	0.8853	-1.8945
SINE $2\pi t/60.83$	-3.6335	1.2002	-3.0274	-3.1864	0.8913	-3.5749
COSINE $2\pi t/60.83$	5.4770	1.1922	4.5940	7.3261	0.8854	8.2743
SINE $2\pi t/45.625$	-7.0983	1.1983	-5.9237	3.1196	0.8899	3.5055
COSINE $2\pi t/45.625$	2.3614	1.1927	1.9799	2.3383	0.8857	2.6399
SINE $2\pi t/30.416$	5.4576	1.1960	4.5630	5.8855	0.8883	6.6259
COSINE $2\pi t/30.416$	7.3075	1.1939	6.1207	4.8832	0.8866	5.5074
MONDAY	4.9537	3.1600	1.5676	-13.4649	2.3468	-5.7376
TUESDAY	-24.6758	3.1599	-7.8090	-12.3116	2.3468	-5.2462
WEDNESDAY	-21.4770	3.1599	-6.7967	-6.6072	2.3467	-2.8155
THURSDAY	3.1168	3.1599	0.9864	1.4130	2.3467	0.6021
FRIDAY	-16.1087	3.1598	-5.0979	-14.3497	2.3467	-6.1149
SAURDAY	2.9663	3.1598	0.9388	-5.9072	2.3467	-2.5173
STATION 2	-316.8735	3.3780	-93.8050	-210.2544	2.5087	-83.8103
STATION 11	-515.6327	3.3780	-152.6443	-327.2490	2.5087	-130.4459
STATION 12	-632.6857	3.3780	-187.2959	-403.3347	2.5087	-160.7747
STATION 14	-118.6830	3.3780	-35.1341	-41.4327	2.5087	-16.5156
STATION 16	-422.9116	3.3780	-125.1958	-268.2694	2.5087	-106.9358
STATION 19	-129.9878	3.3780	-38.4807	-63.0939	2.5087	-25.1501
STATION 20	-80.2680	3.3780	-23.7620	-75.0231	2.5087	-29.9052

STATION 1 BASE LEVEL

TABLE 2.17

RESULTS WITH COMBINED MODEL

SHOPPING CENTER SITES

	REGULAR GRADE			PREMIUM GRADE		
	COEFF.	COEFF. S.D.	T VALUE	COEFF.	COEFF. S.D.	T VALUE
R		.8926			.8764	
S.E.E.		44.3233			33.9405	
CONSTANT		280.4513			239.0135	
LINEAR TREND		0.0132	24.8224	0.0936	0.0101	9.2946
t^2		0.1722	-14.2481	-0.1236	0.1319	-0.9370
SINE $2\pi t/365$		1.0313	-14.9808	-4.1947	0.7898	-5.3114
COSINE $2\pi t/365$		0.9734	-9.6357	-8.5241	0.7454	-11.4357
SINE $2\pi t/182.5$		0.9685	8.3559	3.7896	0.7416	5.1097
COSINE $2\pi t/182.5$		0.9443	10.9208	6.6926	0.7231	9.2554
SINE $2\pi t/91.25$		0.9520	-2.3646	-0.6394	0.7290	-0.8772
COSINE $2\pi t/91.25$		0.9421	5.9473	2.2481	0.7214	3.1161
SINE $2\pi t/60.83$		0.9486	1.0480	-2.5949	0.7264	-3.5725
COSINE $2\pi t/60.83$		0.9422	2.1692	2.2215	0.7215	3.0790
SINE $2\pi t/45.625$		0.9471	-0.5179	-0.0320	0.7252	-0.0441
COSINE $2\pi t/45.625$		0.9426	-0.6454	1.7018	0.7218	2.3577
SINE $2\pi t/30.416$		0.9453	3.6141	2.3666	0.7238	3.2694
COSINE $2\pi t/30.416$		0.9436	2.5336	2.7070	0.7225	3.7466
MONDAY		-44.5371	-17.8330	-34.0086	1.9124	-17.7830
TUESDAY		-24.7848	-9.9249	-24.4831	1.9124	-12.8023
WEDNESDAY		-33.0149	-13.2198	-26.2355	1.9124	-13.7188
THURSDAY		-33.5400	-13.4302	-23.7483	1.9124	-12.4183
FRIDAY		-29.9472	-11.9916	-25.8453	1.9123	-13.5150
SATURDAY		-19.5064	-7.8109	-15.2709	1.9123	-7.9855
STATION 9		-66.6571	-28.8299	-79.2027	1.7705	-44.7353
STATION 15		-213.2340	-92.2260	-174.4585	1.7705	-98.5378
STATION 17		-137.4245	-59.4375	-133.9265	1.7705	-75.6445
STATION 18		-15.8844	-6.8702	-65.4000	1.7705	-36.9393
STATION 25		-17.3497	-7.5039	-47.0980	1.7705	-26.6019

TABLE 2.18

STATION 4 BASE LEVEL

FINAL MODEL INTERSTATE SITES

REGULAR GASOLINE SALES

$$R = 0.9435$$

$$S.E.E. = 84.8889$$

$$CONSTANT = 1039.0321$$

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	0.2543
QUADRATIC TERM ($t^2/10000$)	2.6709
SINE $2\pi t/365$	-36.3728
COSINE $2\pi t/365$	-28.4145
SINE $2\pi t/182.5$	9.7200
COSINE $2\pi t/182.5$	25.3959
SINE $2\pi t/91.25$	-11.8001
SINE $2\pi t/45.625$	- 8.7491
COSINE $2\pi t/30.416$	10.9320
MONDAY	-95.0402
TUESDAY	-103.4126
WEDNESDAY	-109.5715
THURSDAY	-79.3702
FRIDAY	-99.2300
SATURDAY	-55.7914
STATION 5	-129.1673
STATION 6	-431.9388
STATION 7	91.9279
STATION 21	169.0746

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

<u>VARIABLE</u>	<u>COEFFICIENT</u>
QUADRATIC TERM ($t^2/10000$)	3.4174
SINE $2\pi t/365$	-15.0133
COSINE $2\pi t/365$	- 7.1024
SINE $2\pi/182.5$	12.2106
COSINE $2\pi t/182.5$	30.7986
COSINE $2\pi t/60.83$	10.9012
COSINE $2\pi t/45.625$	6.3302
SINE $2\pi t/30.416$	11.3062
COSINE $2\pi t/30.416$	6.8380
MONDAY	-76.5594
TUESDAY	-61.0477
WEDNESDAY	-53.2159
THURSDAY	-43.8597
FRIDAY	-64.7196
SATURDAY	-31.9346
STATION 5	-63.7415
STATION 6	-270.7796
STATION 7	59.2830.
STATION 21	106.5306

STATION 3 BASE LEVEL

TABLE 2.20

FINAL MODEL BUSINESS SITES

REGULAR GASOLINE SALES

R = 0.9444

S.E.E. = 66.4963

CONSTANT = 638.3573

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	-0.1193
QUADRATIC TERM ($t^2/10000$)	5.0494
SINE $2\pi t/365$	-19.6778
COSINE $2\pi t/365$	-14.6007
COSINE $2\pi t/182.5$	14.5107
SINE $2\pi t/91.25$	-8.2859
COSINE $2\pi t/91.25$	-6.1459
SINE $2\pi t/45.625$	-7.9362
SINE $2\pi t/30.416$	6.8879
COSINE $2\pi t/30.416$	8.8597
MONDAY	-21.7322
TUESDAY	-55.4310
WEDNESDAY	-51.4041
THURSDAY	-21.2484
FRIDAY	-44.6465
STATION 10	-176.2463
STATION 13	-170.1578
STATION 22	23.8748
STATION 23	348.3660
STATION 24	94.7116

STATION 8 BASE LEVEL

TABLE 2.21

FINAL MODEL BUSINESS SITES

PREMIUM GASOLINE SALES

$$R = 0.9355$$

$$S.E.E. = 55.2687$$

$$CONSTANT = 404.9542$$

<u>VARIABLE</u>	<u>COEFFICIENT</u>
QUADRATIC TERM ($t^2/10000$)	1.9708
SINE $2\pi t/365$	-11.0927
COSINE $2\pi t/365$	7.1907
SINE $2\pi t/182.5$	9.0687
COSINE $2\pi t/182.5$	21.7148
COSINE $2\pi t/60.83$	10.0956
SINE $2\pi t/30.416$	8.5432
COSINE $2\pi t/30.416$	6.3386
MONDAY	-39.7810
TUESDAY	-34.8004
WEDNESDAY	-30.7454
THURSDAY	-19.3237
FRIDAY	-38.3967
SATURDAY	-15.5502
STATION 10	-96.6585
STATION 13	-93.1850
STATION 22	67.5401
STATION 23	317.5714
STATION 24	69.5279

STATION 8 BASE LEVEL

TABLE 2.22

FINAL MODEL RESIDENTIAL SITES

REGULAR GASOLINE SALES

R = 0.9593

S.E.E. = 65.0018

CONSTANT = 820.2547

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	-0.1196
QUADRATIC TERM ($t^2/10000$)	4.0138
SINE $2\pi t/365$	-16.3765
COSINE $2\pi t/365$	-11.2872
COSINE $2\pi t/182.5$	11.7024
SINE $2\pi t/91.25$	- 7.0411
COSINE $2\pi t/60.83$	5.4748
SINE $2\pi t/45.625$	- 7.1069
COSINE $2\pi t/30.416$	7.3079
TUESDAY	-27.4447
WEDNESDAY	-24.2403
FRIDAY	-18.8636
STATION 2	-316.8735
STATION 11	-515.6327
STATION 12	-632.6857
STATION 14	-118.6830
STATION 16	-422.9116
STATION 19	-129.9878
STATION 20	-80.2680

STATION 1 BASE LEVEL

TABLE 2.23

FINAL MODEL RESIDENTIAL SITES

PREMIUM GASOLINE SALES

$$R = 0.9469$$

$$S.E.E. = 48.3272$$

$$CONSTANT = 525.0679$$

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	-0.0861
QUADRATIC TERM ($t^2/10000$)	2.1075
SINE $2\pi t/365$	-7.9508
COSINE $2\pi t/365$	4.8872
SINE $2\pi t/182.5$	7.4710
COSINE $2\pi t/182.5$	17.6112
COSINE $2\pi t/60.83$	7.3238
SINE $2\pi t/30.416$	5.9047
COSINE $2\pi t/30.416$	4.8754
MONDAY	-7.2528
THURSDAY	7.6211
FRIDAY	-8.1436
STATION 2	-210.2544
STATION 11	-327.2490
STATION 12	-403.3347
STATION 14	-41.4327
STATION 16	-268.2694
STATION 19	-63.0939
STATION 20	-75.0231

STATION 1 BASE LEVEL

TABLE 2.24

FINAL MODEL SHOPPING CENTER SITES

REGULAR GASOLINE SALES

$$R = .8918$$

$$S.E.E. = 44.4480$$

$$CONSTANT = 280.3977$$

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	0.3259
QUADRATIC TERM ($t^2/10000$)	-2.4364
SINE $2\pi t/365$	-15.3731
COSINE $2\pi t/365$	-9.3452
SINE $2\pi t/182.5$	8.1361
COSINE $2\pi t/182.5$	10.3640
COSINE $2\pi t/91.25$	5.6580
MONDAY	-44.5386
TUESDAY	-24.7832
WEDNESDAY	-33.0112
THURSDAY	-33.5353
FRIDAY	-29.9428
STATION 9	-66.6571
STATION 15	-213.2340
STATION 17	-137.4245
STATION 18	-15.8844
STATION 25	-17.3497

STATION 4 BASE LEVEL

TABLE 2.25

FINAL MODEL SHOPPING CENTER SITES

PREMIUM GASOLINE SALES

$$R = 0.8749$$

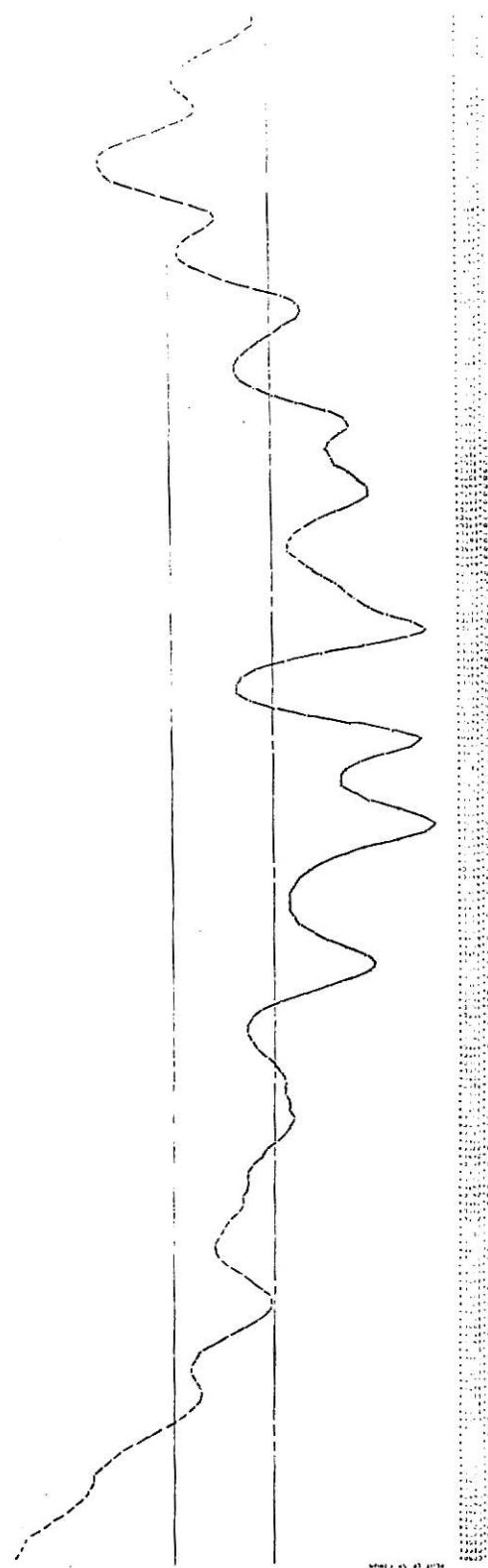
$$S.E.E. = 34.1023$$

$$CONSTANT = 239.7498$$

<u>VARIABLE</u>	<u>COEFFICIENT</u>
LINEAR TREND	0.0857
SINE $2\pi t/365$	-4.0688
COSINE $2\pi t/365$	-8.6276
SINE $2\pi t/182.5$	3.8573
COSINE $2\pi t/182.5$	6.7138
COSINE $2\pi t/30.416$	2.7554
MONDAY	-33.9975
TUESDAY	-24.4720
WEDNESDAY	-26.2250
THURSDAY	-23.7392
FRIDAY	-25.8383
SATURDAY	-15.2670
STATION 9	-79.2027
STATION 15	-174.4585
STATION 17	-133.9265
STATION 18	-65.4000
STATION 25	-47.0980

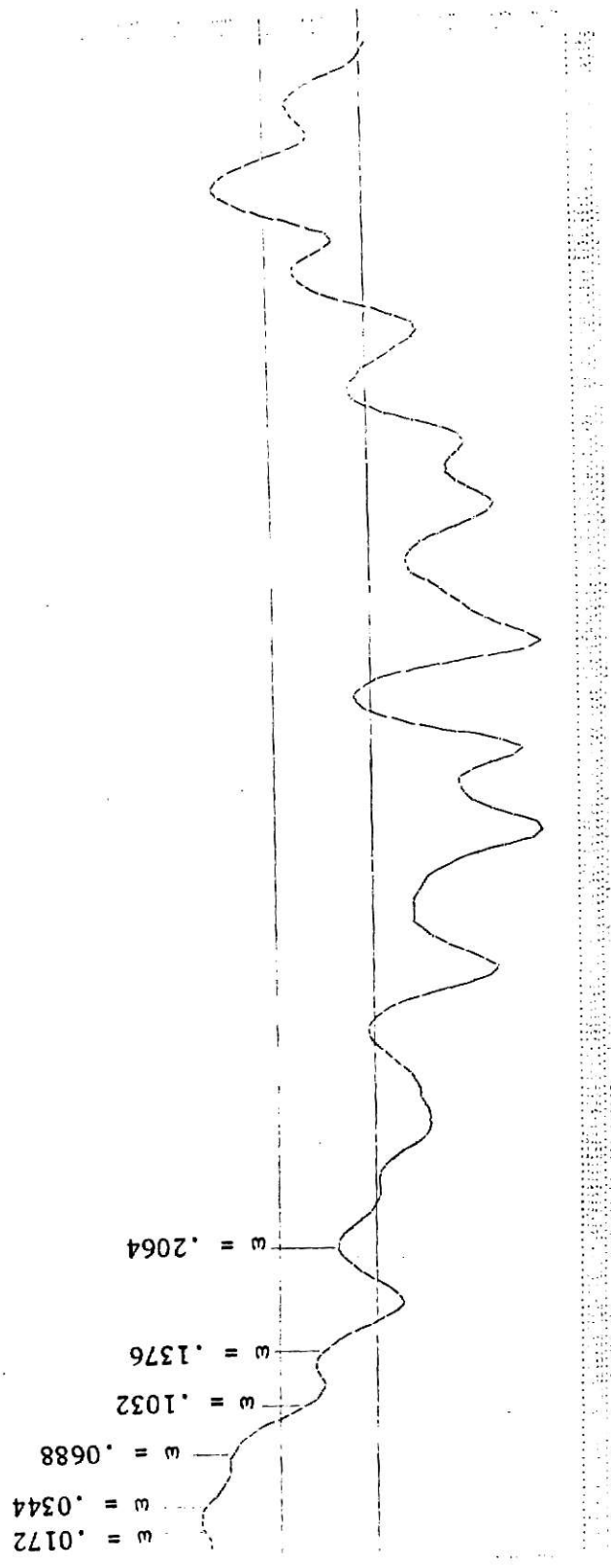
STATION 4 BASE LEVEL

TABLE 2.26



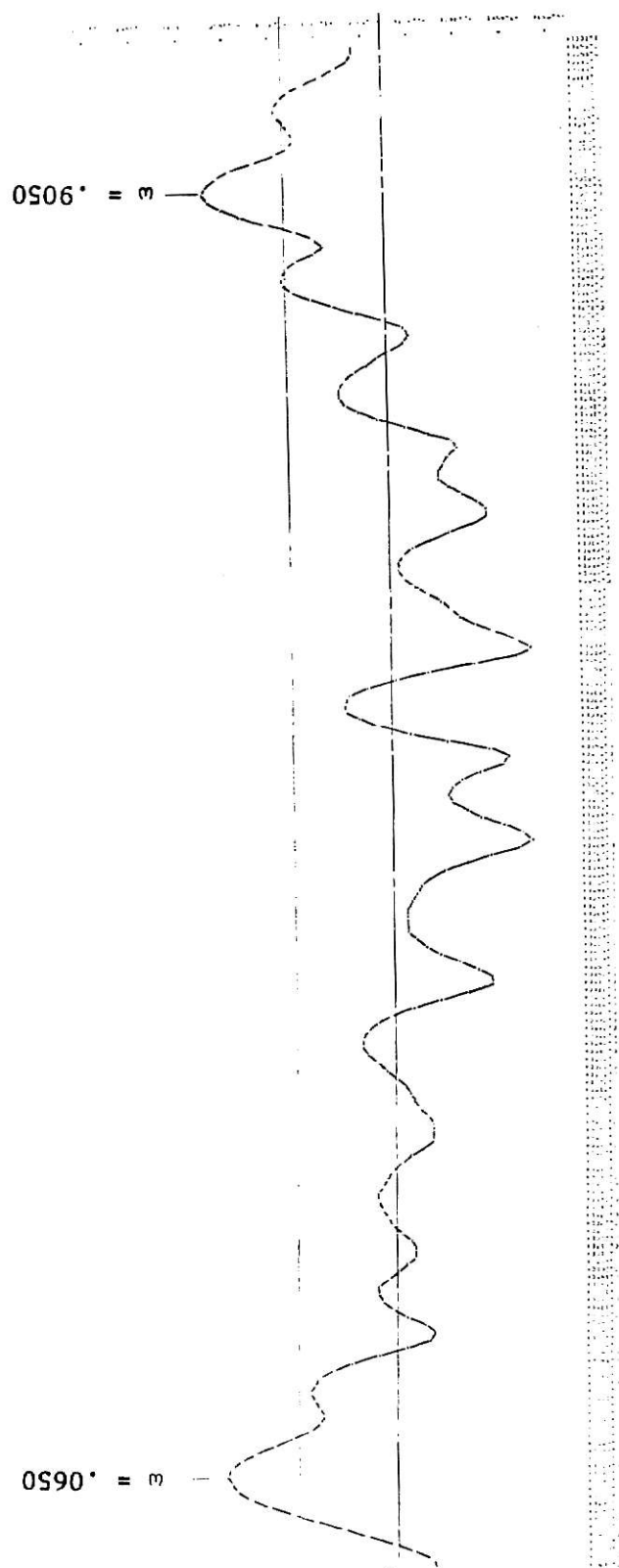
UCL = -.9848
 $\bar{S} = -2.1097$

FIGURE 2.1



UCL = -.708
 $\bar{S} = -1.8320$

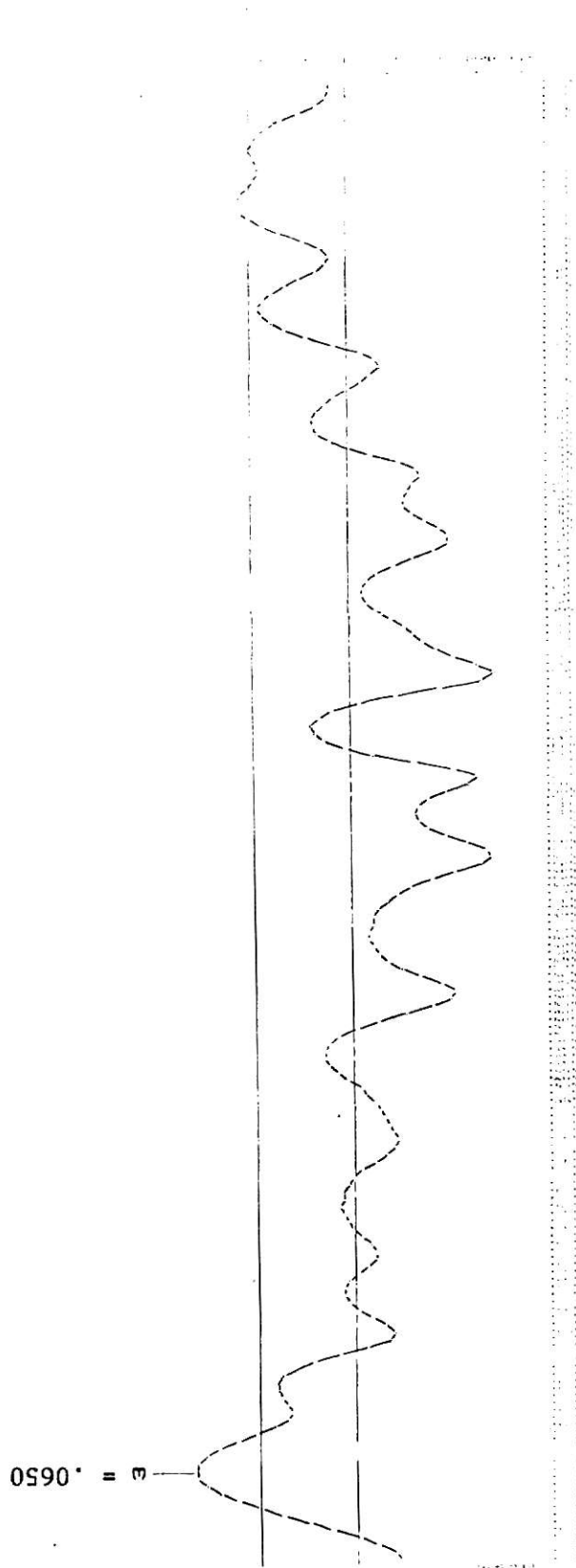
FIGURE 2.2



UCL = -.9848

$\bar{S} = -2.1097$

FIGURE 2.3



ANALYSIS OF DATA BY STRATIFICATION

REGULAR GRADE GASOLINE - STATION 23

		DAY TO DAY						
		MON	TUE	WED	THU	FRI	SAT	SUN
MEAN		1017.61	969.44	971.93	1020.19	985.33	1032.15	1046.15
STD. DEV.		148.43	128.29	134.60	125.85	136.40	122.53	122.68
		WEEKENDS - WEEKDAYS						
		WEEKENDS		WEEKDAYS				
MEAN		1039.13		992.44				
STD. DEV.		121.94		136.73				
		WINTER, FALL, SPRING - SUMMER						
		OTHER		SUMMER				
MEAN		991.82		1045.31				
STD. DEV.		136.64		118.11				
		1967 - 1968						
		1967		1968				
MEAN		944.70		1069.38				
STD. DEV.		105.15		131.90				

FIGURE 2.5

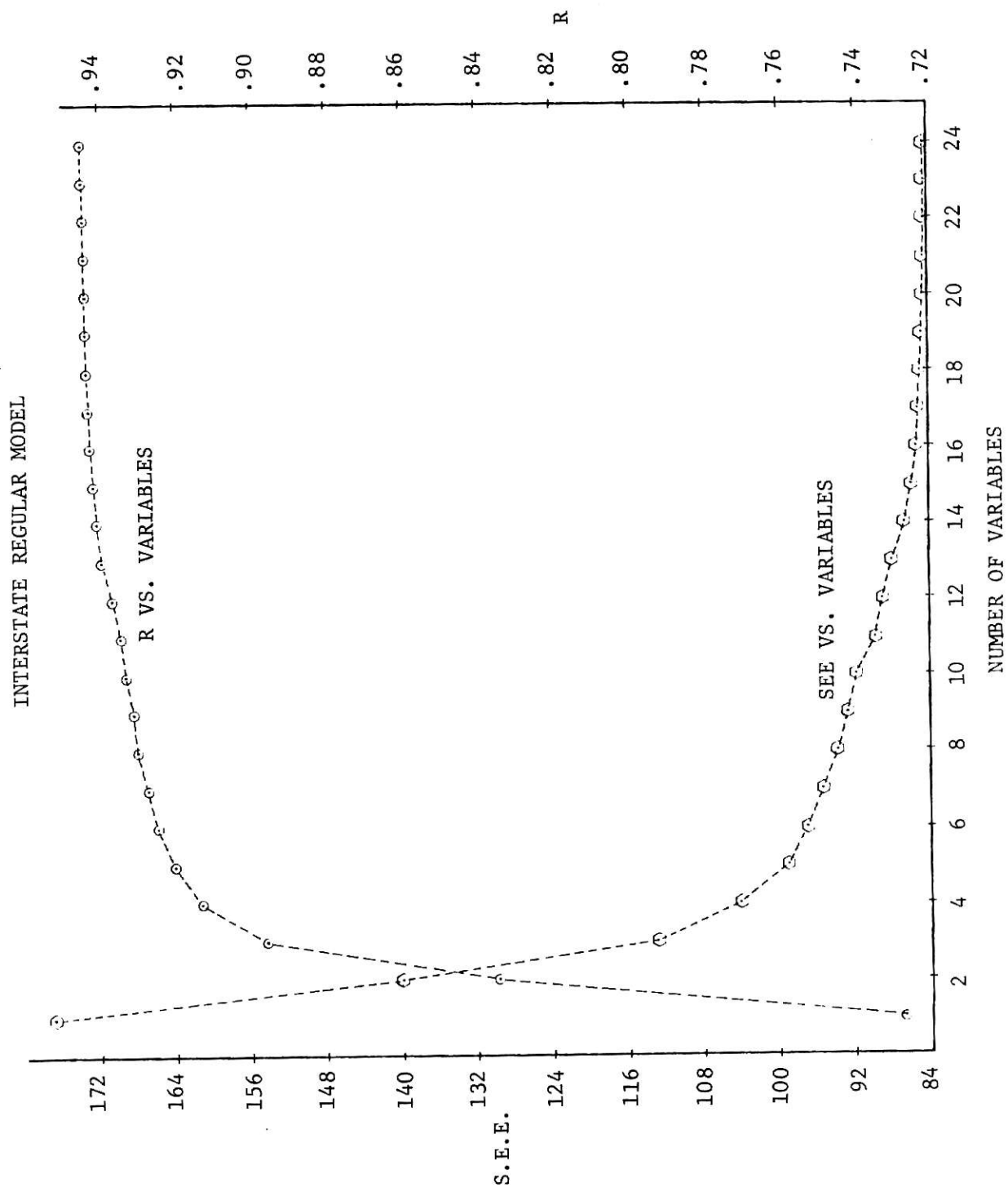


FIGURE 2.6

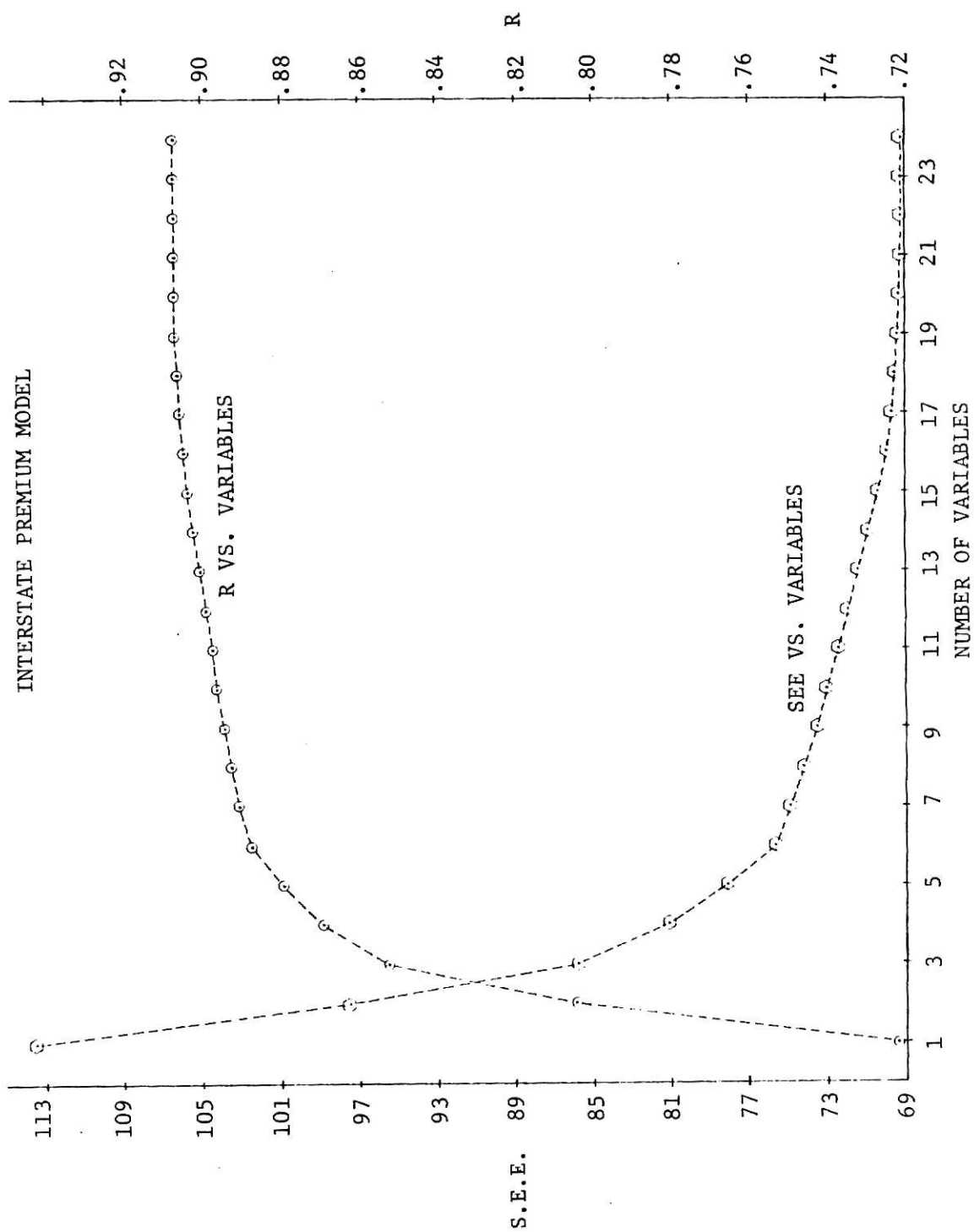


FIGURE 2.7

BUSINESS REGULAR MODEL

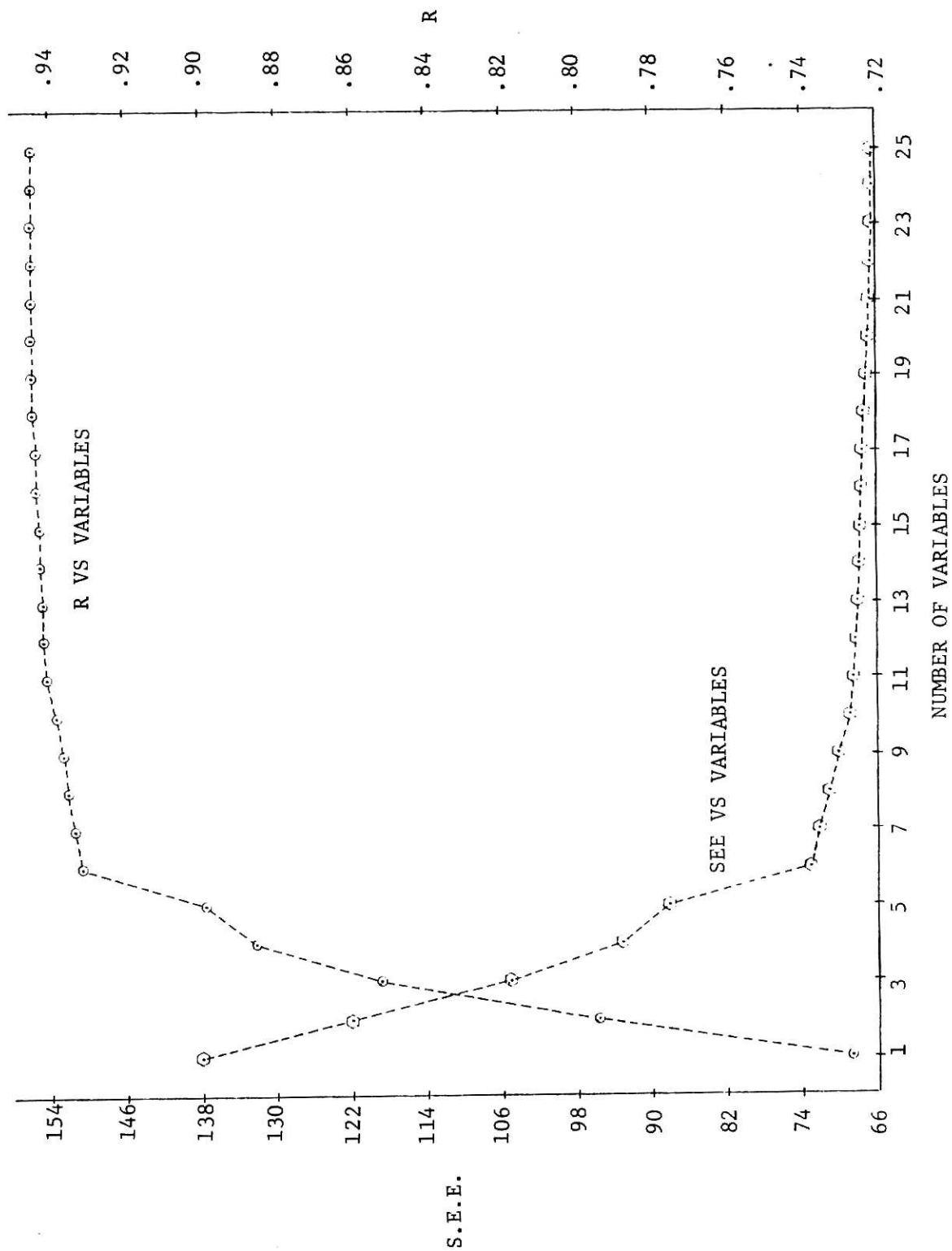


FIGURE 2.8

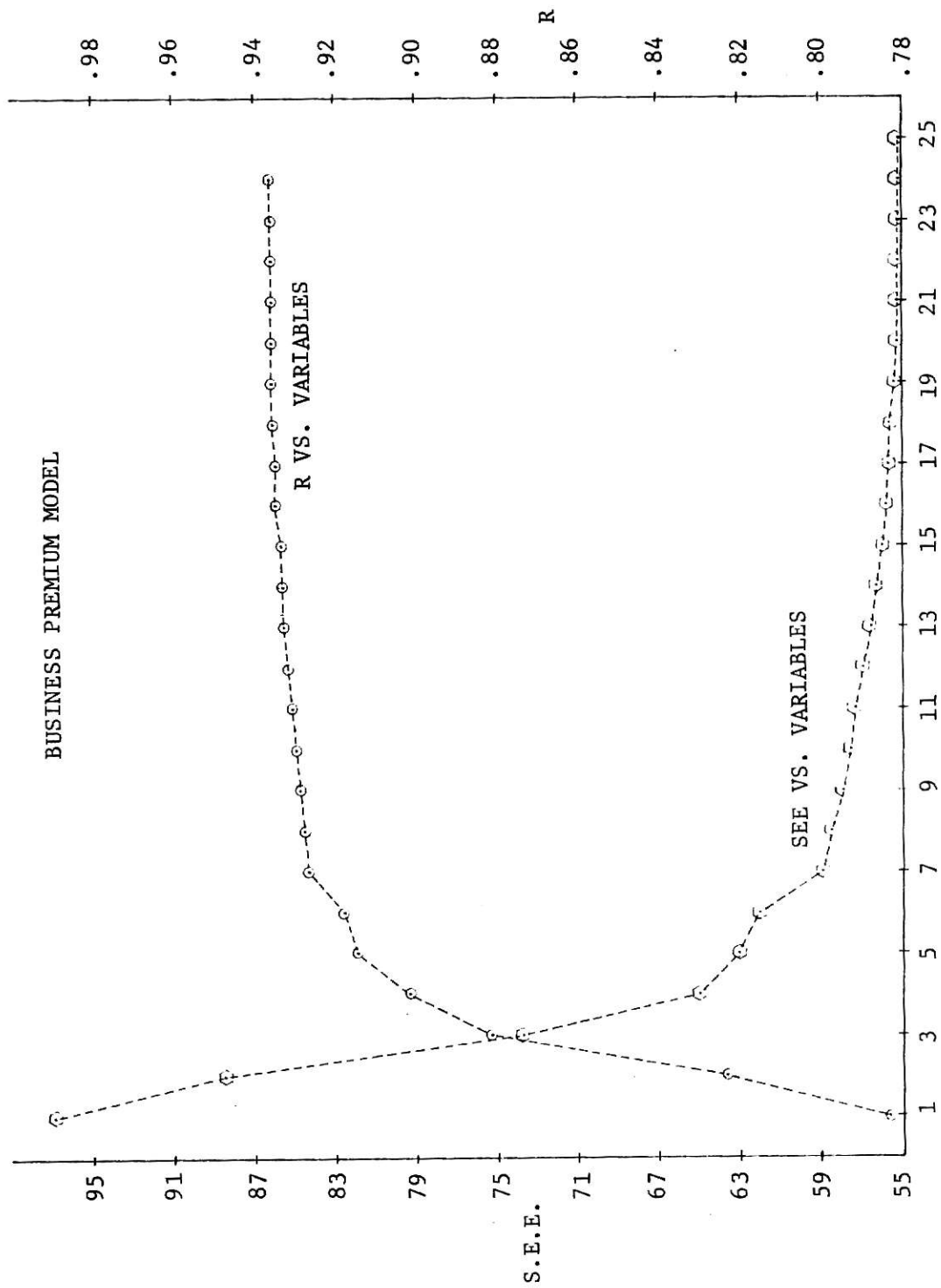
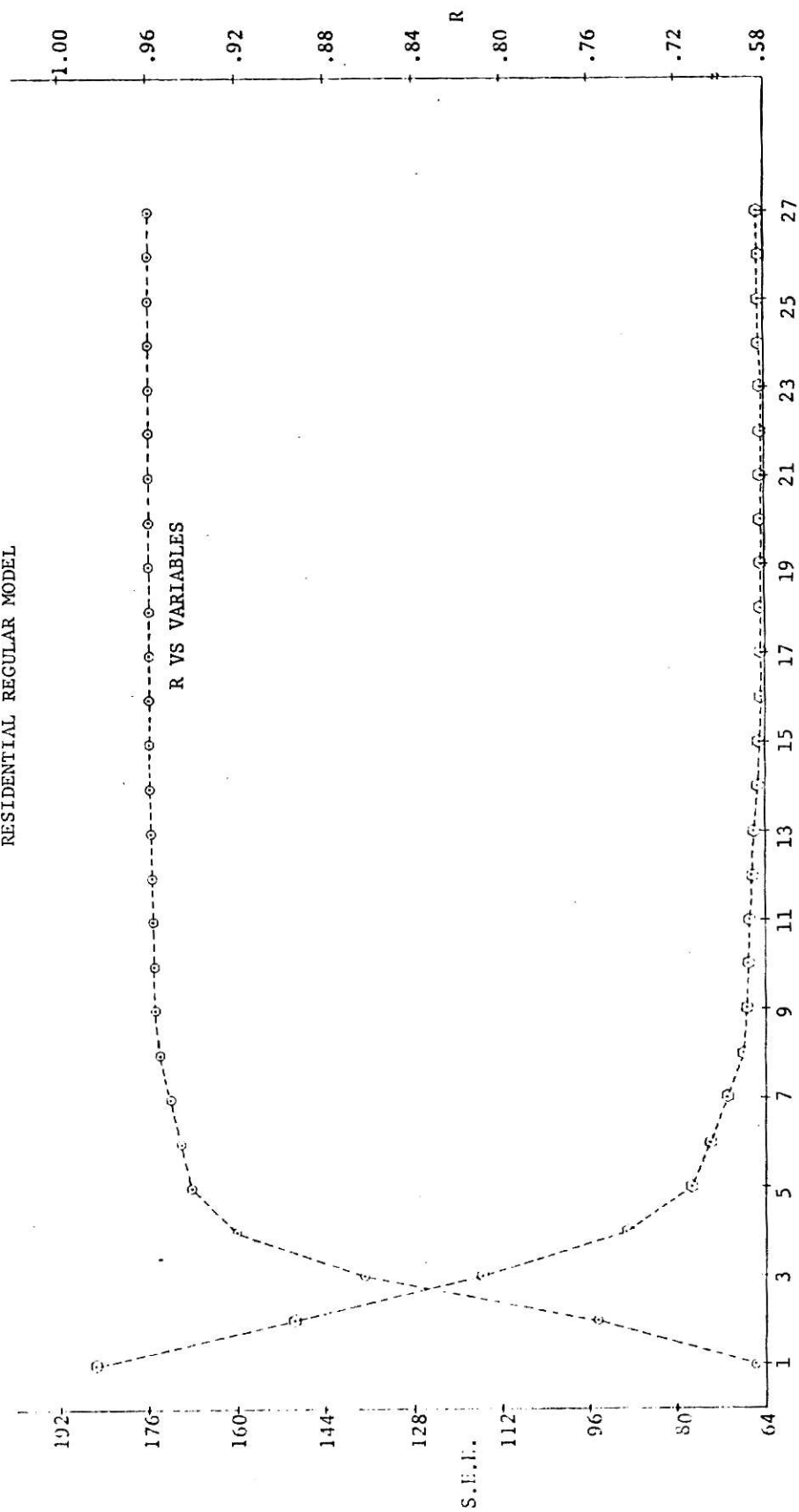


FIGURE 2.9

RESIDENTIAL REGULAR MODEL



NUMBER OF VARIABLES

FIGURE 2.10

RESIDENTIAL PREMIUM MODEL

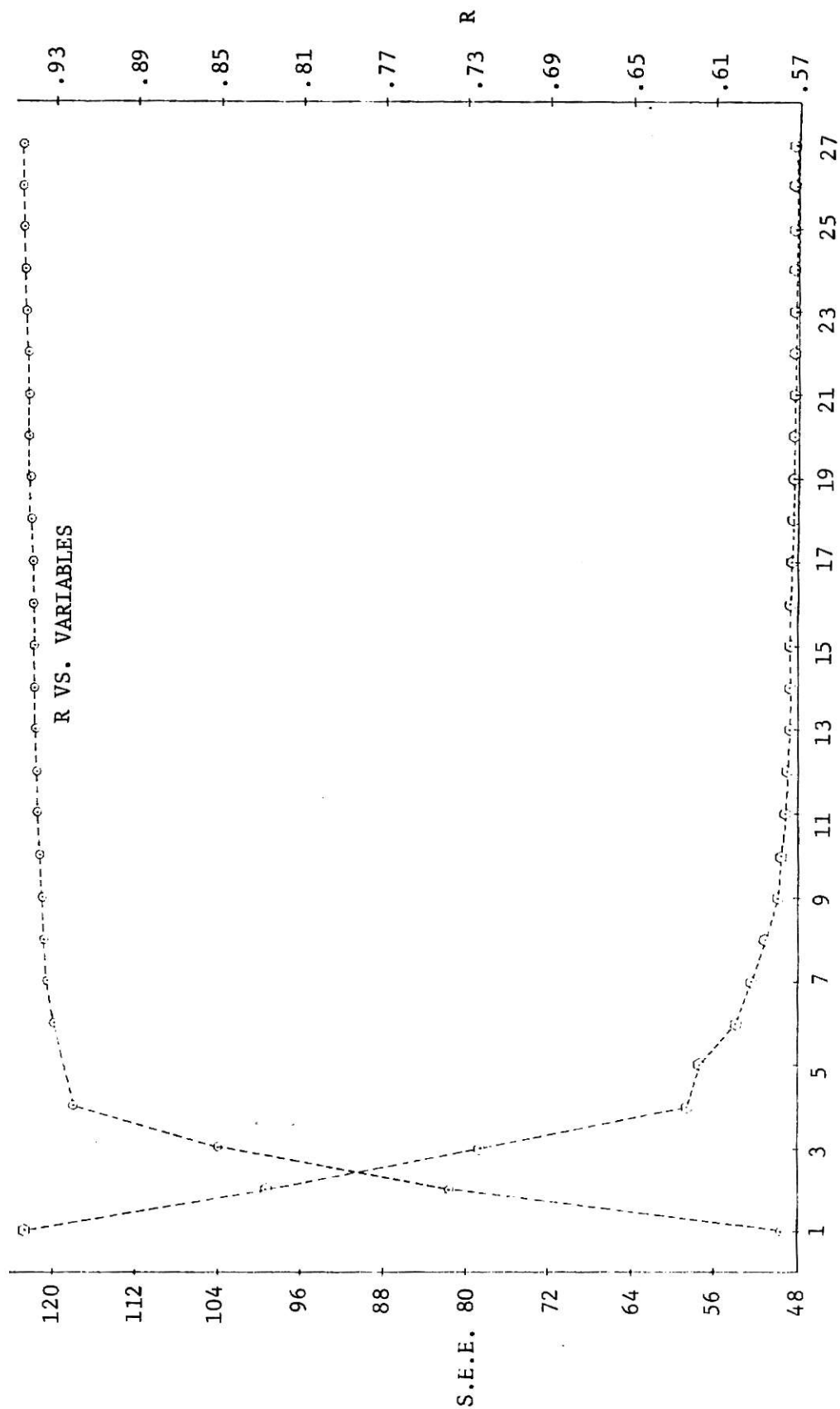


FIGURE 2.11

SHOPPING CENTER REGULAR MODEL

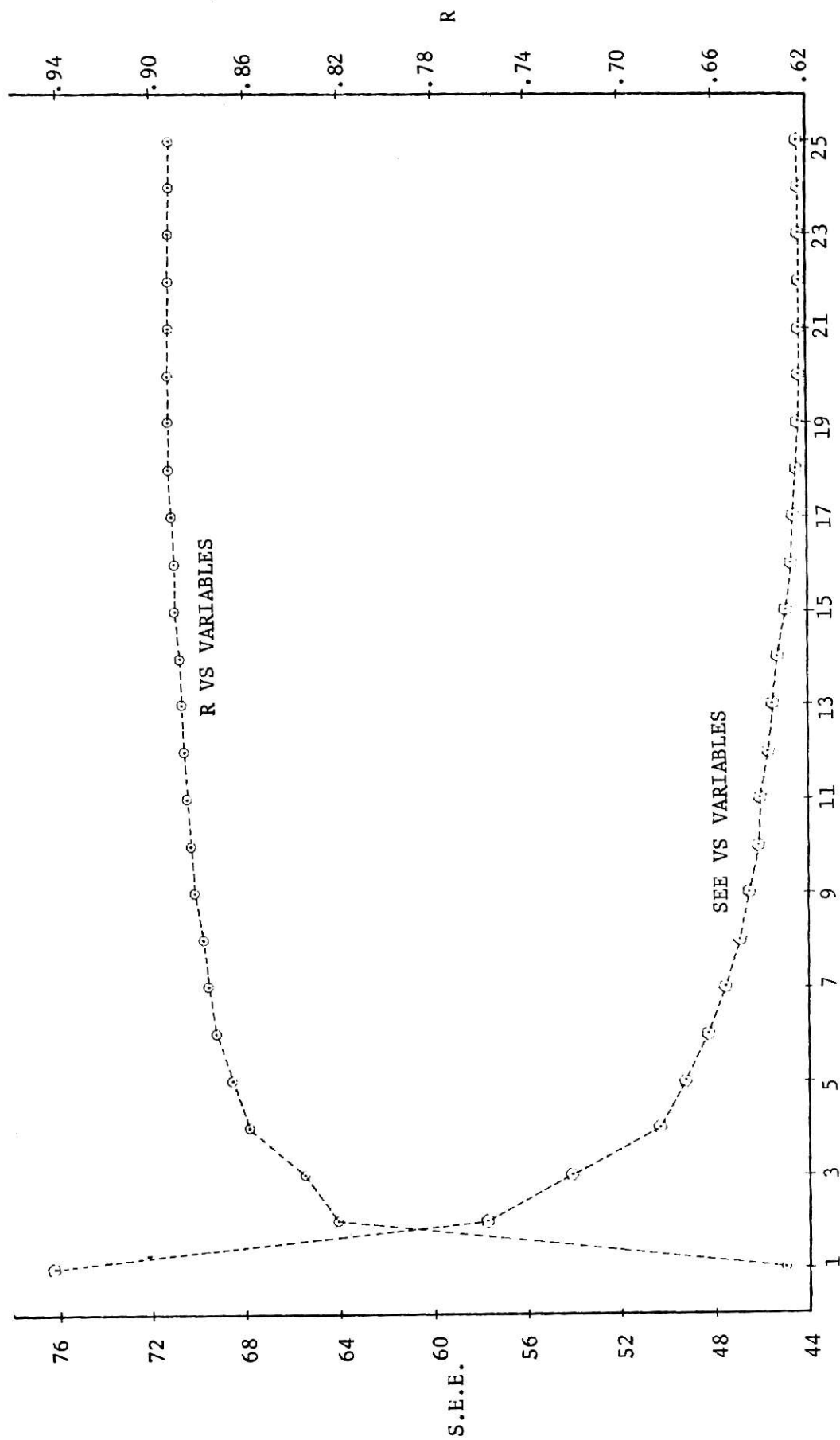


FIGURE 2.12

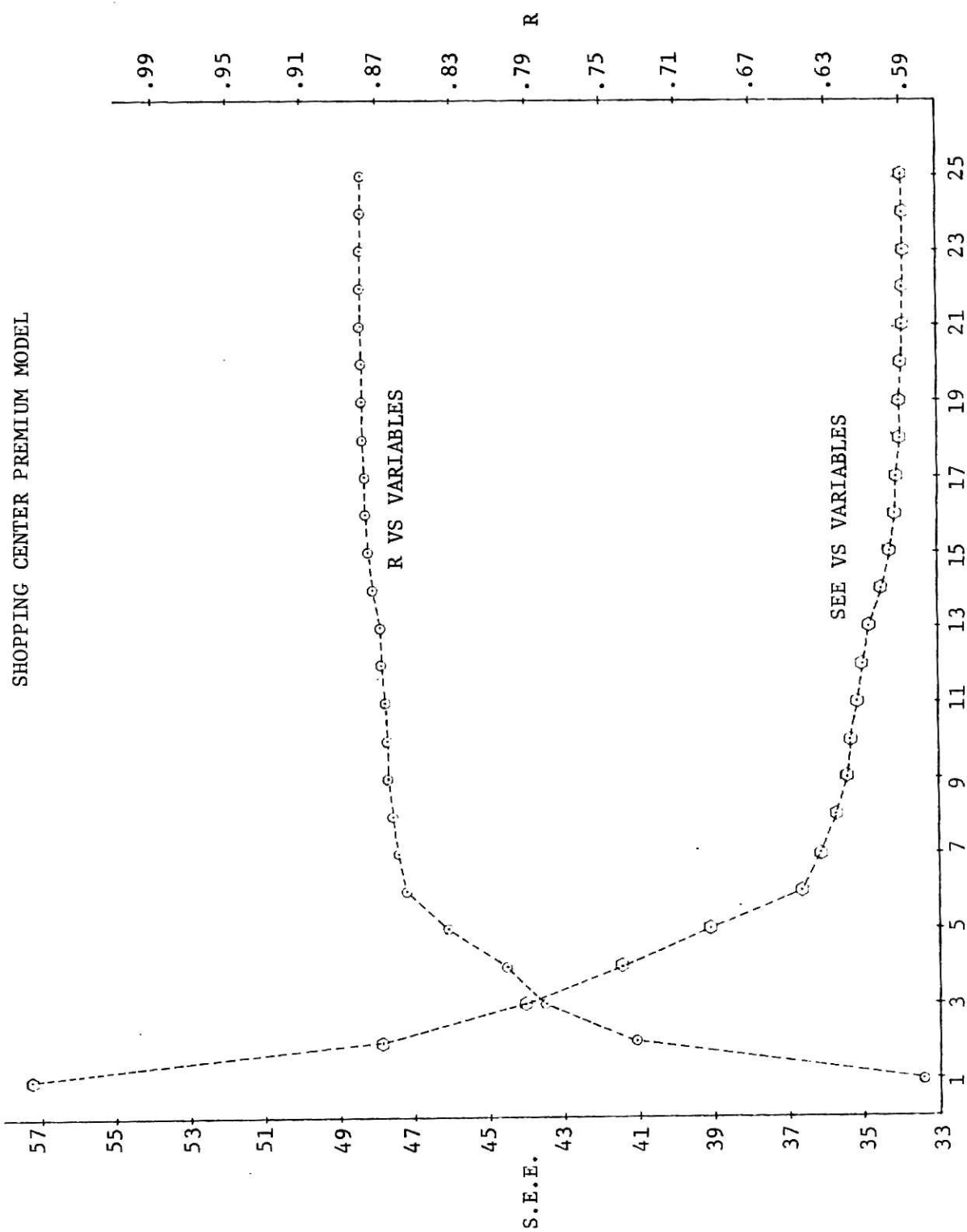


FIGURE 2.13

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 insufficient 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 tabulated, 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 minimum 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 difficult 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 2×25 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 2×25 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.

$$DRA = DRF + \epsilon$$

$$DPA = DPF + \epsilon$$

Where $\epsilon \sim NID(0, \sigma^2)$

σ = 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:

$$z = \frac{((1-N)^{-.16239} - 1.) \cdot .20517 - (N^{-.16239} - 1.) \cdot .20517}{.3240}$$

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.

σ = 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:

$$\text{SMRM}(J,6) = \text{SMRM}(J,6) - \text{DRF}$$

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

$$\text{SMRM}(J,8) = \text{SMRM}(J,8) - \text{DRA}$$

$$\text{SMRM}(J,9) = \text{SMRM}(J,9) - \text{DPA}$$

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.

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.

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:

$$\text{SMRM}(J,9) \leq \text{SMRM}(J,5)$$

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

The reorder quantity is determined:

$$\text{OFILE}(2,J) = \text{SMRM}(J,3) - \text{SMRM}(J,9),$$

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.

$$RTTIM \leq VMRM(J,3)$$

RTTIM = Total route time.

VMRM(J,3) = Length of single shift + maximum allowable overtime for one shift.

2. Restriction on vehicle daily usage.

$$VMRM(J,14) + RTTIM \leq VMRM(J,2)$$

VMRM(J,14) = The total time of all routes permanently assigned to vehicle J in the current day.

VMRM(J,2) = The maximum daily availability of vehicle J.

3. Restriction on vehicle load.

$$TLOAD(1,J) \leq VMRM(J,5)$$

$$TLOAD(2,J) \leq VMRM(J,6)$$

TLOAD(1,J) = Regular load quantity.

TLOAD(2,J) = Premium load quantity.

VMRM(J,5) = Regular compartment capacity.

VMRM(J,6) = Premium compartment capacity.

In the case of the non-compartmentalized vehicles, the first equation only is needed.

$$TLOAD(J) \leq VMRM(J,5)$$

TLOAD(J) = Load quantity.

VMRM(J,5) = 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.,

$$\text{if } \text{OFILE}(\text{I},\text{J}) \cdot \text{DF} \geq \text{TLOAD}(\text{I},\text{J}).$$

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, $\text{VMRM}(\text{J},14)$, is updated by the addition of the time of the new route:

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

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

$d_{T,1}$ = distance from the terminal to station 1.

$d_{T,2}$ = 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 $d_{1,2}$ = 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 expressible 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:

1	2	3	4	5	6	.	.	.	24	25
INIDX	2	7	8	10	13	0	.	.	0	0

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 $SAV(I,J)$, $1 \leq J \leq 4$, $(J + 1) \leq I \leq 5$, I varied most rapidly. With the indirect index, $SAV((INIDX(I), INIDX(J)))$ would be indexed, with $1 \leq J \leq (JDX-1)$, $(J + 1) \leq I \leq JDX$, 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:

Station	From	To
1	T	T
2	T	T
3	T	T
4	T	T
5	T	T

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:

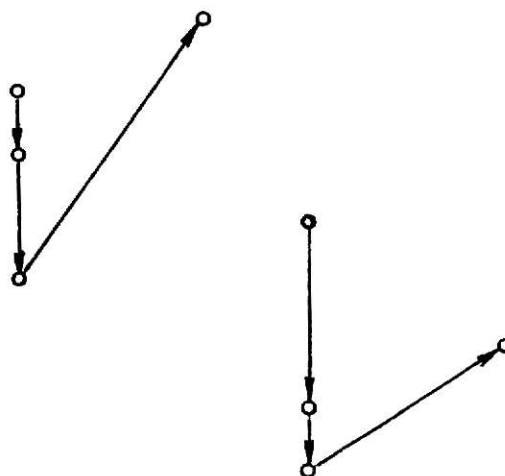
Station	From	To
1	T	T
2	T	T
3	T	5
4	T	T
5	3	T

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.

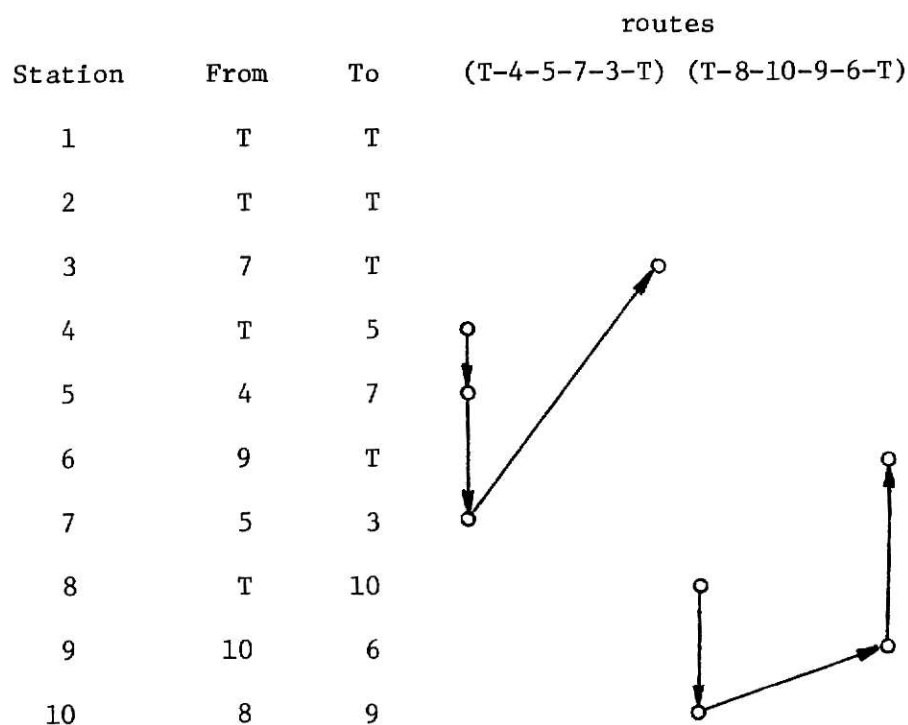
Example:

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

Station	From	To	Routes	
			(T-4-5-7-3-T)	(T-6-9-10-8-T)
1	T	T		
2	T	T		
3	7	T		
4	T	5		
5	4	7		
6	T	9		
7	5	3		
8	10	T		
9	6	10		
10	9	8		

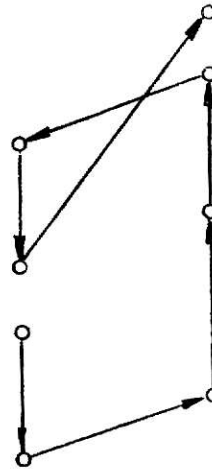


and the maximum savings results from linking stations 4 and 6, it must be determined that the flow will be from 4 to 6, or from 6 to 4. The direction does not really matter, however in this case both points are indicated as being the starting points of their routes. To create the new route, either route may be reversed. Reversing the route of station 6 yields:



The entries in each column for the points on this route are merely exchanged. Thus in linking 6 and 4, the matrix becomes:

Station	From	To	route
			(T-8-10-9-6-4-5-7-3-T)
1	T	T	
2	T	T	
3	7	T	
4	6	5	
5	4	7	
6	9	4	
7	5	3	
8	T	10	
9	10	6	
10	8	9	



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 vehicles 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 simulation.

3.6.5 Summary of Modified Algorithm

1. Savings in terms of costs are calculated.

$$SAV(I,J) = CM(T,I) + CM(T,J) - CM(I,J)$$

$SAV(I,J)$ = Savings obtained by linking points I and J.

$CM(I,J)$ = Cost of transit on link I-J.

$CM(T,I)$ = Cost of transit on link T-I.

$CM(T,J)$ = 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 feasibility:

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

$$IROUT(I,1) \geq 1$$

$$IROUT(J,1) \geq 1$$

where $IROUT(I,1)$ = 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.

$$IROUT(I,4) \neq IROUT(J,4)$$

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.

$$TLOAD(1,I) + TLOAD(1,J) \leq VMRM(K,5)$$

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,

$$TLOAD(2,I) + TLOAD(2,J) \leq VMRM(K,6)$$

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.

VMRM(K,3) = 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.

ECHO CHECK OF INPUT DATA

TOTAL SIMULATED TIME 504 DAYS
 NUMBER OF STATIONS 25
 NUMBER OF VEHICLES 1
 NUMBER OF SHIFTS 1
 NUMBER OF STATION CHARACTERISTICS INPUT 9
 NUMBER OF VEHICLE CHARACTERISTICS INPUT 7
 NUMBER OF MODELS 8
 NUMBER OF MODEL TERMS 22
 NUMBER OF TRIG. TERMS 6
 SEED VALUE 132785

COST OF REGULAR GASOLINE AT THE TERMINAL 0.110 PER GALLON
 COST OF PREMIUM GASOLINE AT THE TERMINAL 0.120 PER GALLON
 INVENTORY CARRYING COST (% PRODUCT COST) 0.130 PER YEAR
 DRIVERS WAGES 3.500 PER HOUR
 VEHICLE MAINTENANCE COST 0.135 PER MILE
 VEHICLE OPERATING COST 0.160 PER MILE
 TAXES AND LICENSING 1200.00 PER VEHICLE PER YEAR

CONSTANT LOADING TIME 0.25 HOURS
 LOADING RATE 400.00 GPM
 CONSTANT UNLOADING TIME 0.25 HOURS
 UNLOADING RATE 450.00 GPM
 DELIVERY FACTOR 0.700
 MINIMUM LOADING FACTOR 0.100

MODEL COEFFICIENTS

COEFFICIENT	1	2	3	4	5	6	7	8
1	1031.0320	638.3572	820.2546	280.3975	700.3398	404.9539	525.0679	239.7498
2	0.2543	-0.1193	-0.1196	0.3259	0.0	0.0	-0.0861	0.0857
3	7.6709	5.0494	4.0138	-2.4364	3.4174	1.9708	2.1075	0.0
4	0.0	6.8174	0.0	0.0	11.3062	8.5432	5.9047	0.0
5	10.9320	8.8597	7.3079	0.0	6.8380	6.3386	4.8754	2.7554
6	-8.7491	-7.9362	-7.1069	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	6.3302	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	5.4748	0.0	10.9012	10.0956	7.3238	0.0
10	-11.8001	-8.2859	-7.0411	0.0	0.0	0.0	0.0	0.0
11	0.0	-6.1459	0.0	5.6580	0.0	0.0	0.0	0.0
12	7.7200	0.0	0.0	8.1361	12.2106	9.0687	7.4710	3.8573
13	25.3959	14.5107	11.7024	10.3640	30.7986	21.7148	17.6112	6.7138
14	-34.3728	-19.6778	-16.3705	-15.3731	-15.0133	-11.0927	-7.9508	-4.0698
15	-29.4145	-14.6007	-11.2872	-9.3452	-7.1024	7.1907	4.8872	-8.6276
16	-95.0402	-21.7322	0.0	-44.5386	-76.5594	-39.7810	-7.2528	-33.9975
17	-103.4126	-55.4310	-27.4447	-24.7832	-61.0477	-34.8004	0.0	-24.4720
18	-109.5715	-51.4041	-24.2403	-33.0112	-53.2159	-30.7454	0.0	-26.2250
19	-77.3702	-21.2484	0.0	-33.5353	-43.8597	-19.3237	7.6211	-23.7392
20	-99.2300	-44.6465	-18.8636	-29.9428	-64.7196	-38.3967	-8.1436	-25.8383
21	-55.7914	0.0	0.0	-19.5035	-31.9346	-15.5502	0.0	-15.2670
22	84.8889	66.4563	65.0018	44.4481	69.5207	55.2687	48.3272	34.1023

FIGURE 3.1

INITIAL VALUES FOR TRIGONOMETRIC FUNCTIONS

PERIOD	SINE INCREMENT	INITIAL SINE VALUE	COSINE INCREMENT	INITIAL COSINE VALUE
30.4160	0.2051	0.0	0.9787	1.0000
45.6250	0.1373	0.0	0.9905	1.0000
60.6360	0.1031	0.0	0.9947	1.0000
91.2500	0.0688	0.0	0.9976	1.0000
182.5000	0.0344	0.0	0.9994	1.0000
365.0000	0.0172	0.0	0.9999	1.0000

STATION
NUMBER TYPE

REGULAR CONSTANT

PREMIUM CONSTANT

1	3	0.0	0.0
2	3	-316.8733	-210.2544
3	1	0.0	0.0
4	4	0.0	0.0
5	1	-129.1673	-63.7415
6	1	-431.9387	-270.7795
7	1	91.9279	59.2830
8	2	0.0	0.0
9	4	-66.6571	-79.2027
10	2	-176.2463	-96.6585
11	3	-515.6326	-327.2488
12	3	-632.6855	-403.3345
13	2	-170.1578	-93.1850
14	3	-118.6830	-41.4327
15	4	-213.2340	-174.4585
16	3	-422.9114	-268.2693
17	4	-137.4245	-133.9265
18	4	-15.8844	-65.4000
19	3	-129.9878	-63.0939
20	3	-90.2680	-75.0231
21	1	169.0746	106.5306
22	2	23.8748	67.5401
23	2	348.3660	317.5713
24	2	94.7116	69.5274
25	4	-17.3497	-47.0980

STATION MASTER REFERENCE MATRIX								
NUMBER	1	2	3	4	5	6	7	8
1.	8000.00	4000.00	2000.00	1000.00	7000.00	3820.00	7000.00	3820.00
2.	6000.00	4000.00	1500.00	1000.00	5630.00	1895.00	5630.00	1895.00
3.	12000.00	6000.00	3000.00	1500.00	7600.00	4130.00	7600.00	4130.00
4.	8000.00	4000.00	2000.00	1000.00	5780.00	3816.00	5780.00	3816.00
5.	8000.00	6000.00	2000.00	1500.00	2926.00	1896.00	2926.00	1896.00
6.	8000.00	6000.00	2000.00	1500.00	6300.00	2830.00	6300.00	2830.00
7.	12000.00	6000.00	3000.00	1500.00	3325.00	3540.00	3325.00	3540.00
8.	6000.00	6000.00	1500.00	1500.00	2850.00	2467.00	2850.00	2467.00
9.	8000.00	6000.00	2000.00	1500.00	6390.00	3360.00	6390.00	3360.00
10.	8000.00	6000.00	2000.00	1500.00	4630.00	3420.00	4630.00	3420.00
11.	8000.00	6000.00	2000.00	1500.00	5500.00	5760.00	5500.00	5760.00
12.	8000.00	6000.00	2000.00	1500.00	7790.00	3960.00	7790.00	3960.00
13.	8000.00	6000.00	2000.00	1500.00	3760.00	3010.00	3760.00	3010.00
14.	8000.00	4000.00	2000.00	1000.00	2855.00	1830.00	2855.00	1830.00
15.	8000.00	4000.00	2000.00	1000.00	4930.00	2060.00	4930.00	2060.00
16.	6000.00	4000.00	1500.00	1000.00	5970.00	1758.00	5970.00	1758.00
17.	8000.00	4000.00	2000.00	1000.00	5540.00	1259.00	5540.00	1259.00
18.	6000.00	4000.00	1500.00	1000.00	4320.00	3730.00	4320.00	3730.00
19.	6000.00	4000.00	1500.00	1000.00	4410.00	2620.00	4410.00	2620.00
20.	6000.00	6000.00	1500.00	1500.00	3670.00	3990.00	3670.00	3990.00
21.	12000.00	6000.00	3000.00	1500.00	5720.00	4305.00	5720.00	4305.00
22.	6000.00	6000.00	1500.00	1500.00	2216.00	3000.00	2216.00	3000.00
23.	8000.00	6000.00	2000.00	1500.00	5890.00	5560.00	5890.00	5560.00
24.	6000.00	4000.00	1500.00	1000.00	5320.00	1666.00	5320.00	1666.00
25.	8000.00	4000.00	2000.00	1000.00	4600.00	3820.00	4600.00	3820.00

VEHICLE MASTER REFERENCE MATRIX								
NUMBER	1	2	3	4	5	6	7	8
1.	12.00	12.00	2.00	5000.00	3000.00	8.00	0.0	0.0

DISTANCE MATRIX

[illegible]

TIME MATRIX

[illegible]

STATION STATISTICS

STATION NUMBER	TOTAL NUMBER OF DELIVERIES	AVERAGE DAILY DEMAND	REGULAR	PREMIUM	AVERAGE ORDER SIZE	REGULAR	PREMIUM	AVERAGE INVENTORY LEVEL	STATION INVENTORY CARRYING COST	NUMBER EXPEDITED ORDERS
1	5.	781.2	539.7	3952.3	2619.4	5752.5	2462.9	9.42	9.42	0.
2	4.	507.2	346.8	2819.8	2429.8	4163.1	2259.5	7.40	7.40	0.
3	7.	937.0	716.5	3924.3	2679.1	9316.1	3203.5	14.30	14.30	1.
4	2.	278.3	210.2	4706.7	2842.0	4802.6	2680.0	8.62	8.62	0.
5	7.	821.1	618.5	3748.2	2713.9	5439.7	3148.8	9.90	9.90	0.
6	5.	507.4	428.0	3088.4	2668.7	5810.3	3325.0	10.53	10.53	1.
7	9.	1072.1	762.6	3664.5	2221.0	8738.8	3319.7	13.80	13.80	0.
8	5.	576.7	419.7	3382.9	2597.0	3573.3	3894.6	8.73	8.73	0.
9	2.	208.2	147.5	2452.5	2041.3	5494.5	3622.4	10.54	10.54	0.
10	2.	432.2	308.1	5000.0	2612.1	4553.7	3903.1	9.83	9.83	1.
11	1.	253.6	219.6	5000.0	2664.0	4448.3	4327.6	10.23	10.23	0.
12	1.	167.3	146.7	2761.6	3000.0	6784.6	3118.2	11.37	11.37	1.
13	3.	433.7	336.2	4649.5	3000.0	5458.7	3264.2	10.07	10.07	2.
14	6.	696.3	512.2	3607.7	2399.9	5577.6	2455.0	9.21	9.21	0.
15	1.	63.9	55.7	4352.8	3000.0	5345.9	2210.6	8.66	8.66	1.
16	3.	382.9	292.2	2724.8	2942.6	4564.3	2499.2	8.14	8.14	2.
17	1.	145.2	97.6	2819.4	2946.6	5902.0	2466.7	9.59	9.59	0.
18	1.	261.8	165.5	4582.2	2104.0	3530.1	2739.0	7.27	7.27	1.
19	5.	681.0	503.6	3434.3	2611.0	3926.1	2394.4	7.30	7.30	1.
20	5.	734.1	475.1	4018.5	2657.4	3745.2	4493.4	9.65	9.65	1.
21	8.	1104.5	789.8	4375.1	2772.1	8494.3	3550.2	13.60	13.60	2.
22	5.	648.3	483.4	4083.2	3000.0	3732.0	3397.4	8.30	8.30	1.
23	6.	955.3	739.2	4279.6	3000.0	4916.8	3248.3	9.44	9.44	1.
24	6.	716.1	495.4	3092.9	2449.5	3929.7	2232.7	7.10	7.10	1.
25	2.	263.8	182.5	4595.4	2449.5	4281.1	2651.5	8.01	8.01	0.
TOTAL	102.	13695.1	9994.5	3770.5	2636.6	132280.8	76867.6	241.20	241.20	17.

AVERAGE TOTAL COST C.C0230 PER GALLON SOLD

NUMBER OF DEFERRED ORDERS 4

LST SALES REGULAR 0.0 GALLONS

LST SALES PREMIUM 0.0 GALLONS

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:

$$SMRM(J,8) = SMRM(J,4) + N \cdot (SMRM(J,2) - SMRM(J,4))$$

$$SMRM(J,9) = SMRM(J,5) + N \cdot (SMRM(J,3) - SMRM(J,5))$$

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 idletime. 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)

	Regular	Premium
Monday Factor	- 892	- 618
Tuesday Factor	-1209	- 661
Wednesday Factor	-1240	- 720
Thursday Factor	- 727	- 526
Friday Factor	-1093	- 832
Saturday Factor	- 399	- 380
Sunday Factor	0	0

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

Delivery Factor	Compartment Ratio Premium/Regular		
	3500/4500	3000/5000	2500/5500
.5	8	10	-
.6	2	1	-
.7	2	4	5
.8	5	8	4
.9	7	7	7

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:

Delivery Factor	Total Lost Sales		
	Compartment Ratio Premium/Regular		
	3500/4500	3000/5000	2500/5500
.5	12934	13084	-
.6	7469	5830	-
.7	4817	5856	9326
.8	7442	9537	7603
.9	12772	8410	18702

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 occurring 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:

Delivery Factor	Total Cost	
	Compartment Ratio	
	3500/4500	3000/5000
.5	\$1209.31	\$1202.54
.6	\$1202.23	\$1193.10
.7	\$1215.94	\$1207.93

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 advanced, 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		
<u>STATION</u>	<u>REGULAR</u>	<u>PREMIUM</u>
1	5400	2230
2	5080	2180
3	7970	5890
4	3770	2290
5	7600	2720
6	2564	1838
7	8400	4680
8	3210	4480
9	7140	5350
10	5840	1671
11	6070	4810
12	4360	2072
13	3380	2005
14	7720	1774
15	5130	1417
16	2441	2750
17	6940	2930
18	4330	1081
19	1842	2140
20	4350	2965
21	3672	3235
22	4530	2785
23	2036	4600
24	5380	2560
25	3535	2275

TABLE 4.1

INITIAL CONDITIONS

<u>STATION</u>	<u>STARTING INVENTORY</u>	
	<u>REGULAR</u>	<u>PREMIUM</u>
1	7000	3820
2	5630	1895
3	7600	4130
4	5780	3816
5	2926	1896
6	6300	2830
7	3325	3540
8	2850	2467
9	6390	3860
10	4630	5420
11	5500	5760
12	7790	3960
13	3760	3010
14	2855	1830
15	4930	2060
16	5970	1758
17	5540	1299
18	4320	3730
19	4410	2620
20	3670	3990
21	5720	4305
22	2216	3000
23	5890	5560
24	5320	1666
25	4600	3820

TABLE 4.2

CORRESPONDENCE OF REPORT PERIOD TO DATE

<u>REPORT PERIOD</u>	<u>DATE AT END OF PERIOD</u>
1	JAN. 22, 1967
2	FEB. 19
3	MAR. 19
4	APRIL 16
5	MAY 14
6	JUNE 11
7	JULY 9
8	AUG. 6
9	SEPT. 3
10	OCT. 1
11	OCT. 29
12	NOV. 26
13	DEC. 24
14	JAN. 21, 1968
15	FEB. 18
16	MAR. 17
17	APRIL 14
18	MAY 12
19	JUNE 9
20	JULY 7
21	AUG. 4
22	SEPT. 1
23	SEPT. 29
24	OCT. 27
25	NOV. 24
26	DEC. 22

TABLE 4.3

RESULTS OF SIMULATION

PREMIUM/REGULAR RATIO 2500/5500

	DELIVERY FACTOR		
	.7	.8	.9
TOTAL NUMBER OF TRIPS	116	120	122
AVERAGE VEHICLE LOAD (GALLONS)	6003	5845	5647
NUMBER OF TRIPS WITH EXCESS LOAD	2	2	2
TOTAL GALLONS EXCESS LOAD	249	228	226
TOTAL HOURS OVERTIME	18.3	19.0	19.8
TOTAL HOURS IDLE TIME	15.9	12.9	9.9
TOTAL VEHICLE RELATED COST	1302.57	1316.94	1335.25
AVERAGE DAILY DEMAND (GALLONS)			
REGULAR	15229	15235	15201
PREMIUM	10075	10062	10067
AVERAGE INVENTORY (GALLONS)			
REGULAR	130359	129413	127162
PREMIUM	71306	73542	72593
TOTAL NUMBER OF DELIVERIES	121	124	129
AVERAGE DELIVERY SIZE (GALLONS)			
REGULAR	3496	3424	3262
PREMIUM	2269	2237	2094
NUMBER OF EXPEDITED ORDERS	54	51	68
NUMBER OF DEFERRED ORDERS	41	39	55
GALLONS LOST SALES			
REGULAR	2393	2103	6440
PREMIUM	6933	5500	12262
SYSTEM INVENTORY CARRYING COST	232.09	233.78	230.22
TOTAL COST	1534.66	1550.72	1565.47
AVERAGE COST PER GALLON SOLD	.00217	.00219	.00221

TABLE 4.4

RESULTS OF SIMULATION

PREMIUM/REGULAR RATIO 3000/5000

	DELIVERY FACTOR					
	.5	.6	.7	.8	.9	.7
NORMAL SHIFT LENGTH/SHIFT WITH OVERTIME	8/10	8/10	8/10	8/10	8/10	8/12
TOTAL NUMBER OF TRIPS	96	96	99	103	107	100
AVERAGE VEHICLE LOAD (GALLONS)	7288	7325	7108	6779	6344	7107
NUMBER OF TRIPS WITH EXCESS LOAD	1	2	1	2	2	2
TOTAL GALLONS EXCESS LOAD	51	193	316	139	320	190
TOTAL HOURS OVERTIME	12.5	11.3	12.5	12.0	13.6	5.7
TOTAL HOURS IDLE TIME	30.3	35.0	29.8	23.3	21.2	69.2
TOTAL VEHICLE RELATED COST	1202.54	1193.10	1207.93	1227.36	1246.21	1345.13
AVERAGE DAILY DEMAND (GALLONS)						
REGULAR	15242	15232	15262	15202	15210	15228
PREMIUM	10071	10087	10075	10070	10074	10063
AVERAGE INVENTORY (GALLONS)						
REGULAR	124880	129656	125346	124876	123732	127441
PREMIUM	66457	70660	73956	77430	78240	76929
TOTAL NUMBER OF DELIVERIES	106	97	103	111	114	104
AVERAGE DELIVERY SIZE (GALLONS)						
REGULAR	3953	4237	4158	3879	3699	4099
PREMIUM	2652	2813	2769	2569	2457	2706
NUMBER OF EXPEDITED ORDERS	58	37	39	43	45	23
NUMBER OF DEFERRED ORDERS	44	25	26	30	35	11
GALLONS LOST SALES						
REGULAR	5161	2862	2211	4136	3819	391
PREMIUM	7923	3768	3645	5401	4591	1176
SYSTEM INVENTORY CARRYING COST	219.81	230.19	229.64	233.19	232.96	235.74
TOTAL COST	1422.35	1423.19	1437.57	1460.55	1479.17	1580.87
AVERAGE COST PER GALLON SOLD	.00201	.00201	.00203	.00206	.00209	.00223

TABLE 4.5

RESULTS OF SIMULATION

PREMIUM/REGULAR RATIO 3500/4500

	DELIVERY FACTOR				
	.5	.6	.7	.8	.9
TOTAL NUMBER OF TRIPS	97	98	99	103	106
AVERAGE VEHICLE LOAD (GALLONS)	7203	7210	7071	6826	6573
NUMBER OF TRIPS WITH EXCESS LOAD	2	2	2	2	2
TOTAL GALLONS EXCESS LOAD	203	169	201	152	123
TOTAL HOURS OVERTIME	12.3	12.0	13.1	12.9	13.4
TOTAL HOURS IDLE TIME	28.3	30.9	30.3	25.5	22.6
TOTAL VEHICLE RELATED COST	1209.51	1202.23	1215.94	1229.14	1242.10
AVERAGE DAILY DEMAND (GALLONS)					
REGULAR	15235	15233	15180	15204	15250
PREMIUM	10073	10079	10051	10057	10068
AVERAGE INVENTORY (GALLONS)					
REGULAR	101829	111577	114631	117910	117317
PREMIUM	84065	84062	84441	82310	80938
TOTAL NUMBER OF DELIVERIES	105	100	101	108	113
AVERAGE DELIVERY SIZE (GALLONS)					
REGULAR	4006	4350	4150	3812	3703
PREMIUM	2608	2859	2716	2501	2431
NUMBER OF EXPEDITED ORDERS	50	38	32	39	50
NUMBER OF DEFERRED ORDERS	40	26	22	29	39
GALLONS LOST SALES					
REGULAR	9937	5342	3551	4705	8190
PREMIUM	2997	2127	1266	2737	4582
SYSTEM INVENTORY CARRYING COST	215.54	226.34	230.25	231.36	229.10
TOTAL COST	1424.85	1428.57	1446.19	1460.50	1471.20
AVERAGE COST PER GALLON SOLD	.00201	.00202	.00205	.00207	.00208

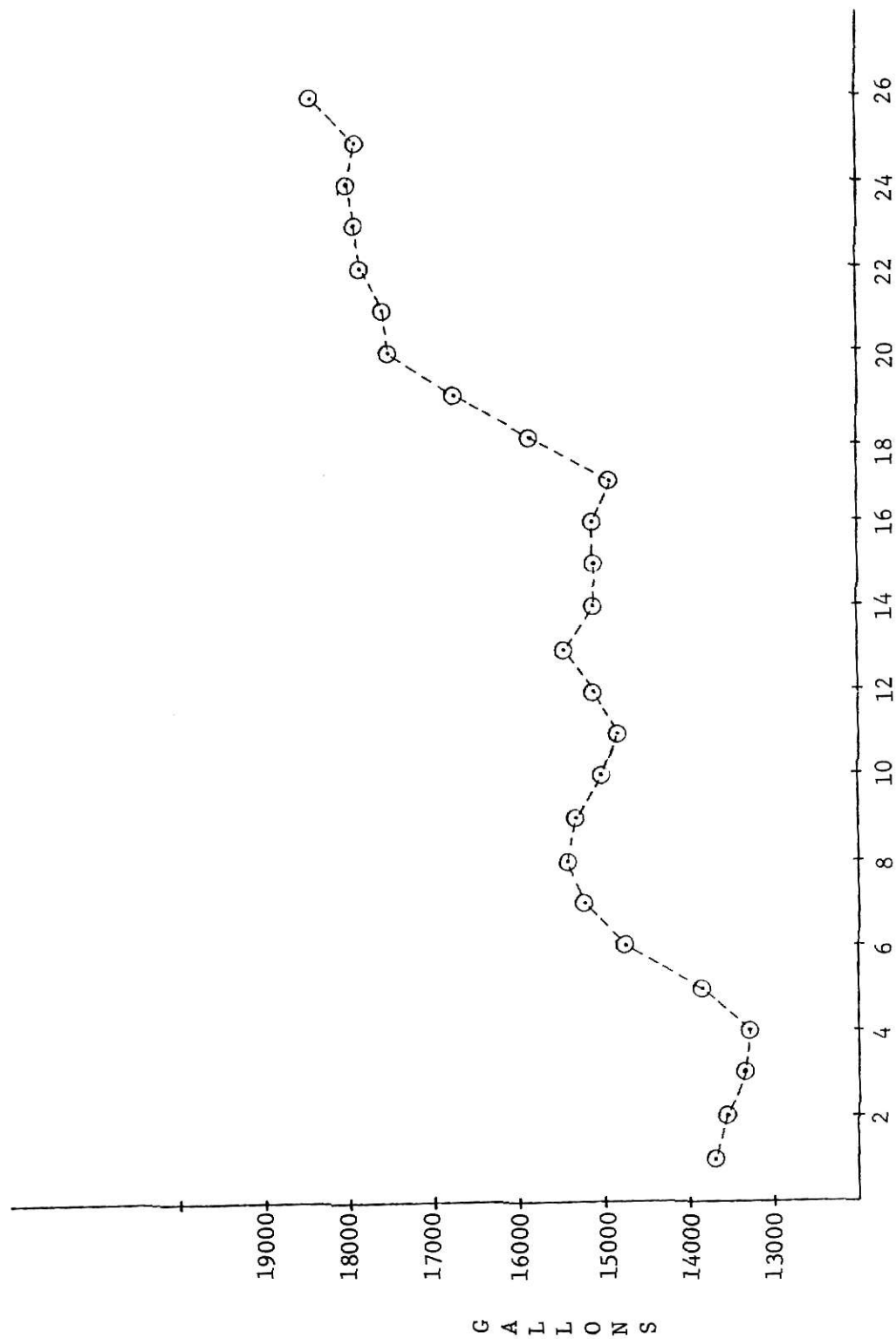
TABLE 4.6

TWELVE MONTH AVERAGES OF STATISTICS NON-COMPARTMENTALIZED VEHICLES

	DELIVERY FACTOR	
	<u>.8</u>	<u>.9</u>
TOTAL NUMBER OF TRIPS	127	130
AVERAGE VEHICLE LOAD (GALLONS)	5444	5343
NUMBER OF TRIPS WITH EXCESS LOAD	13	12
TOTAL GALLONS EXCESS LOAD	12502	11817
TOTAL HOURS OVERTIME	24.9	25.7
TOTAL HOURS IDLE TIME	0	0
TOTAL VEHICLE RELATED COST	1392.47	1399.14
AVERAGE DAILY DEMAND (GALLONS)		
REGULAR	15264	15255
PREMIUM	10084	10076
AVERAGE INVENTORY (GALLONS)		
REGULAR	117402	118630
PREMIUM	67951	68625
TOTAL NUMBER OF DELIVERIES		
REGULAR	79	78
PREMIUM	62	62
AVERAGE DELIVERY SIZE (GALLONS)		
REGULAR	5344	5501
PREMIUM	4083	4146
NUMBER OF EXPEDITED ORDERS		
REGULAR	26	26
PREMIUM	119	116
NUMBER OF DEFERRED ORDERS	124	121
GALLONS LOST SALES		
REGULAR	2272	1433
PREMIUM	28506	24608
SYSTEM INVENTORY CARRYING COST	213.83	216.02
TOTAL COST	1606.30	1615.16
AVERAGE COST PER GALLON SOLD	.00265	.00228

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

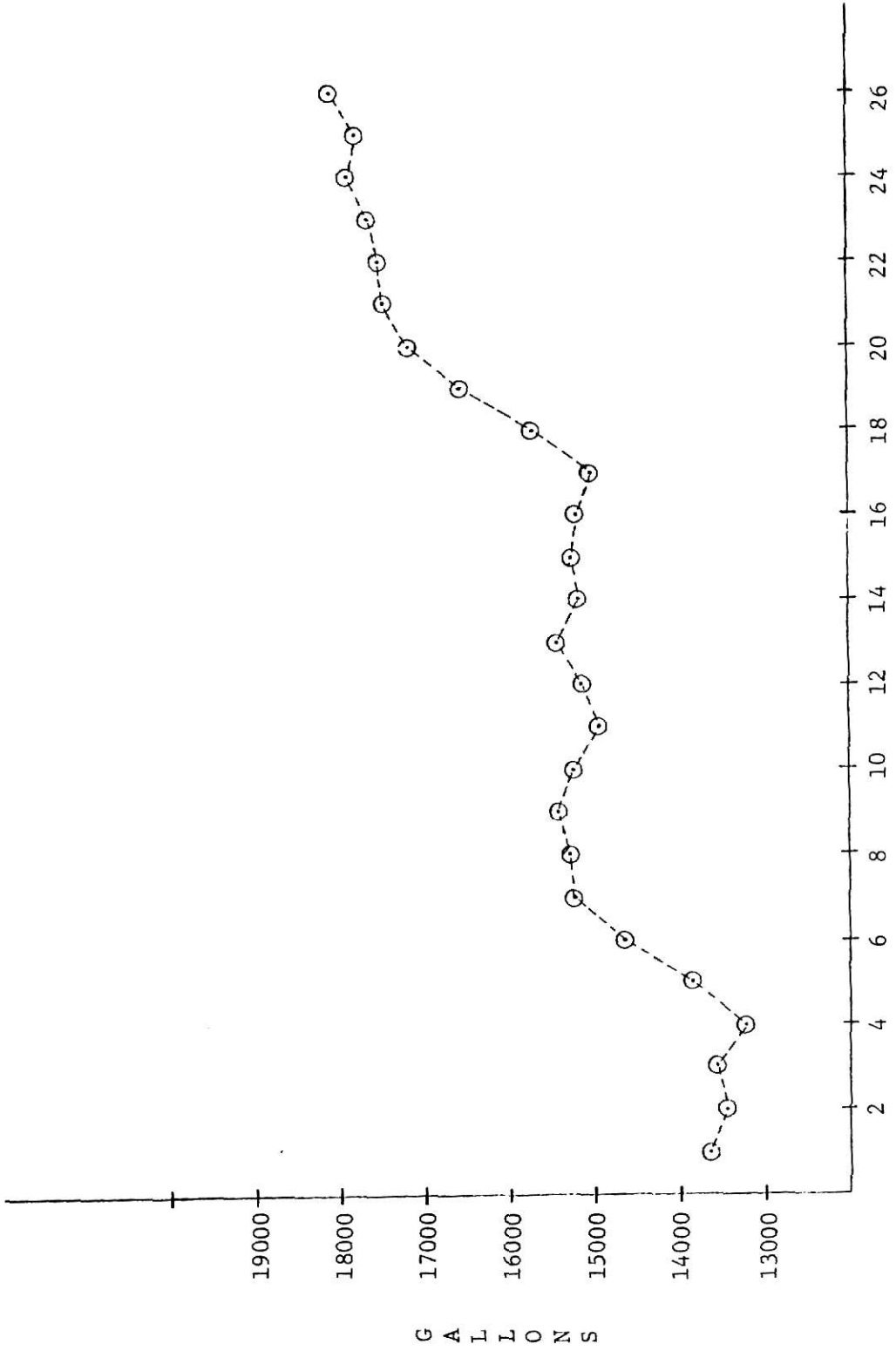


FIGURE 4.2

AVERAGE DAILY DEMAND FOR PREMIUM GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 71747

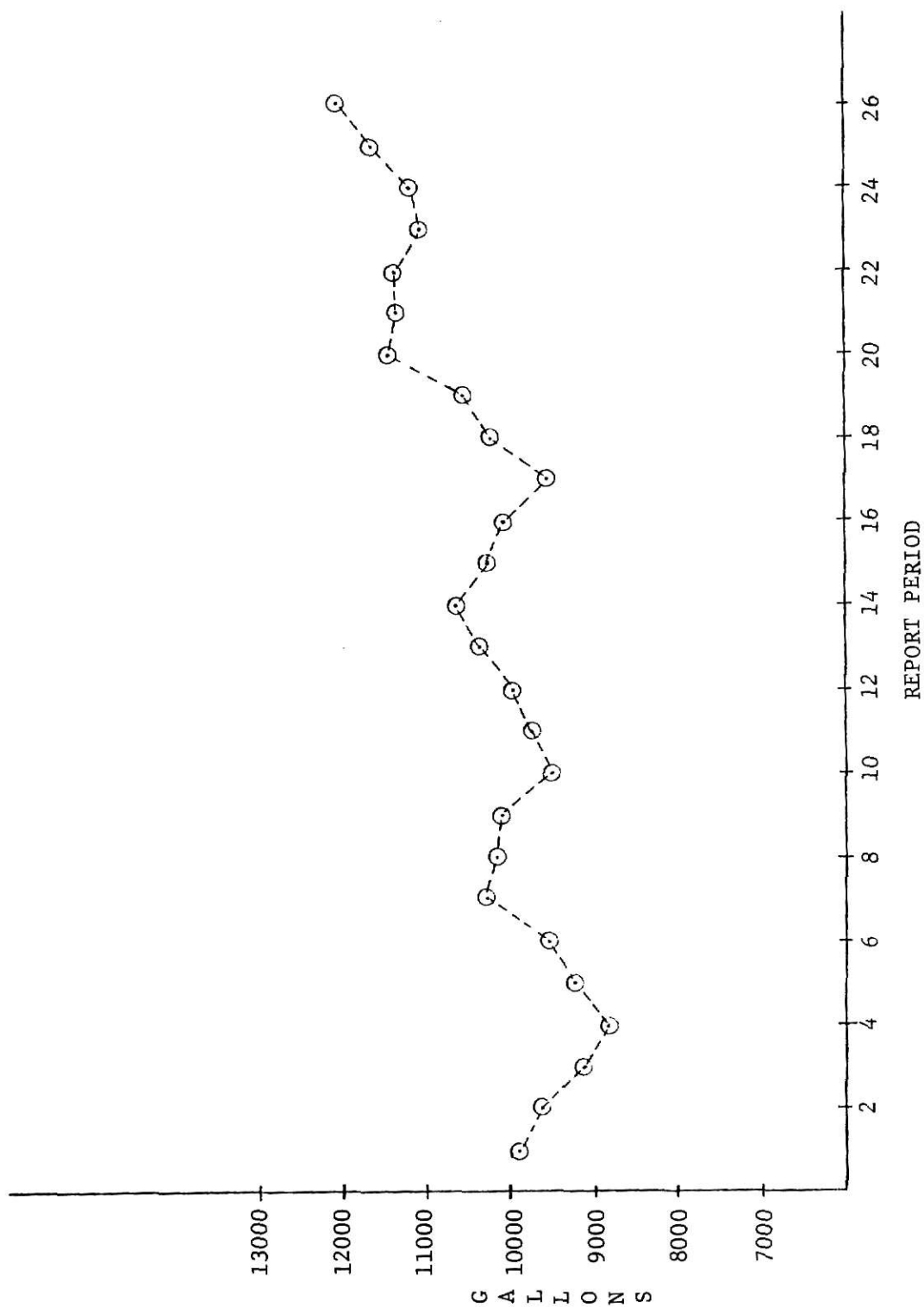


FIGURE 4.3

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

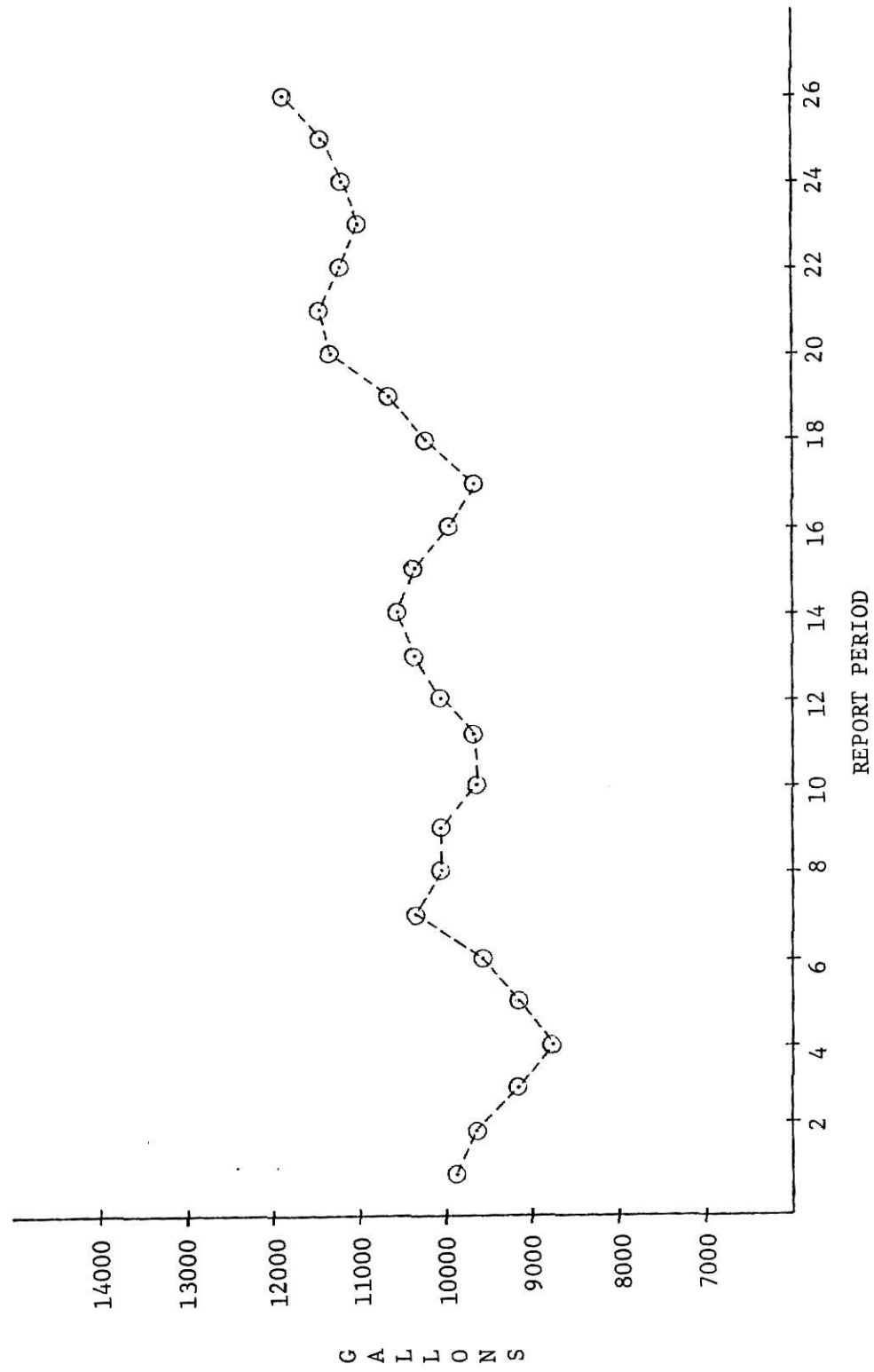


FIGURE 4.4

AVERAGE INVENTORY OF REGULAR GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 71747

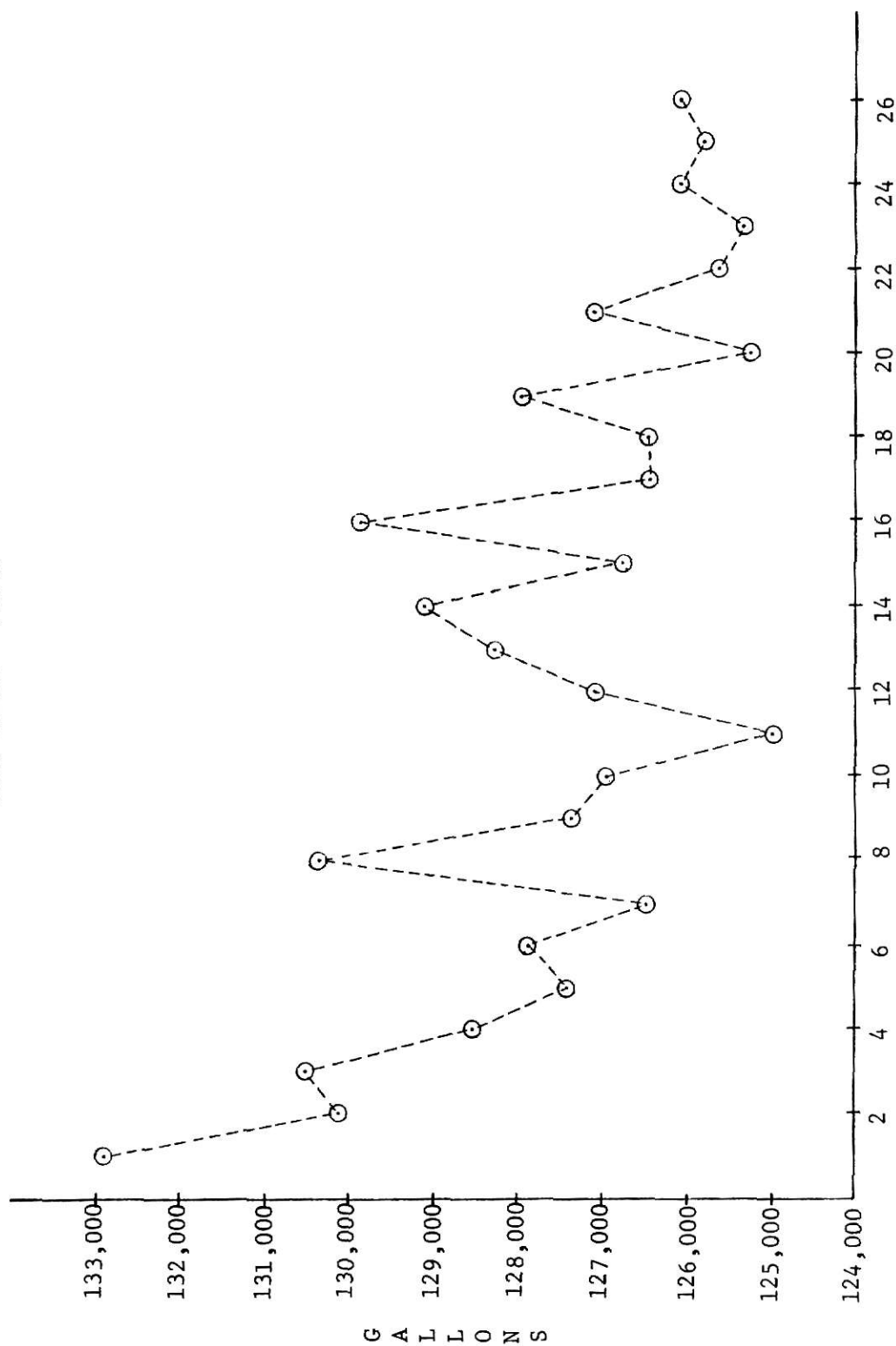


FIGURE 4.5

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

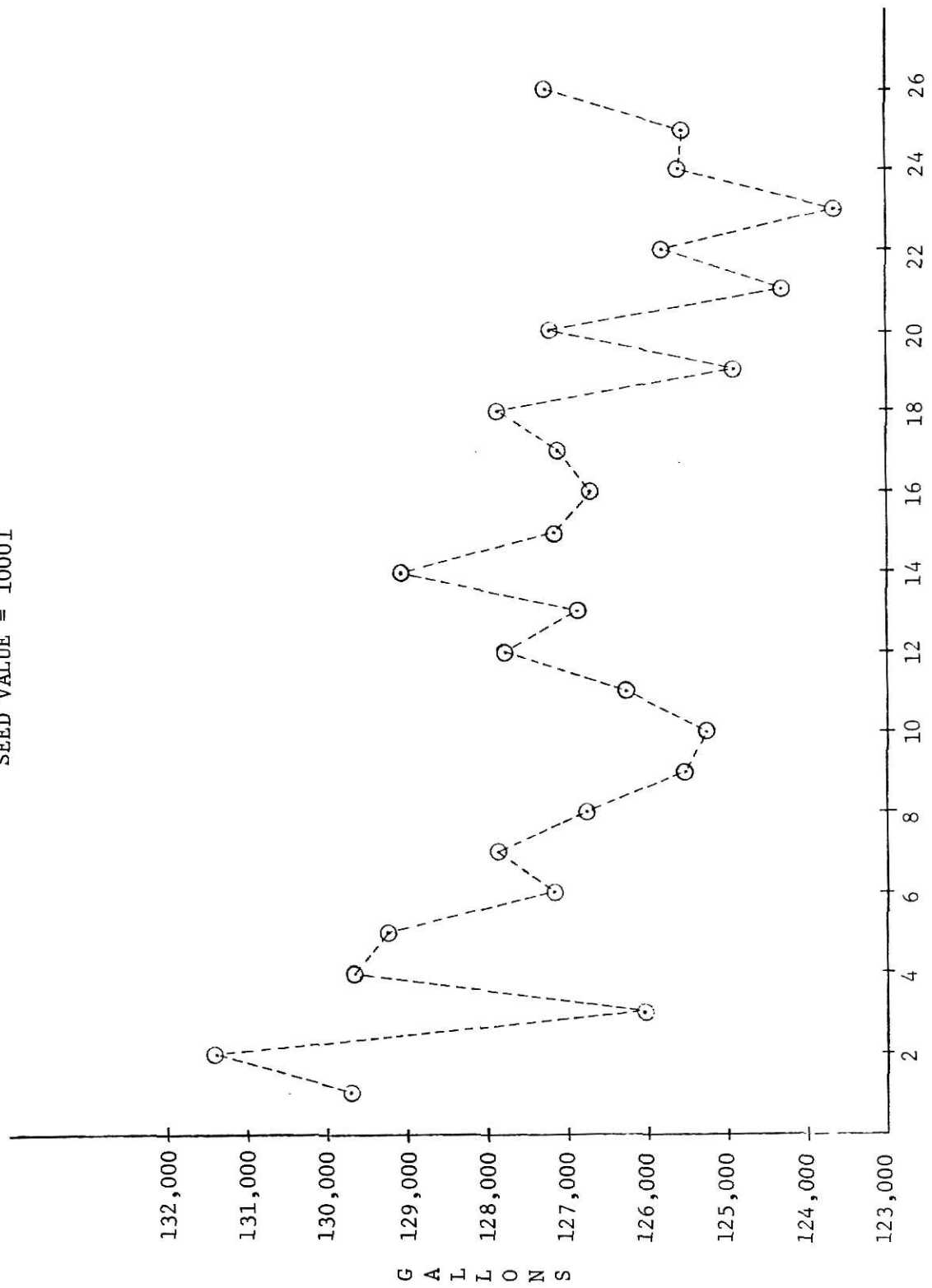


FIGURE 4.6

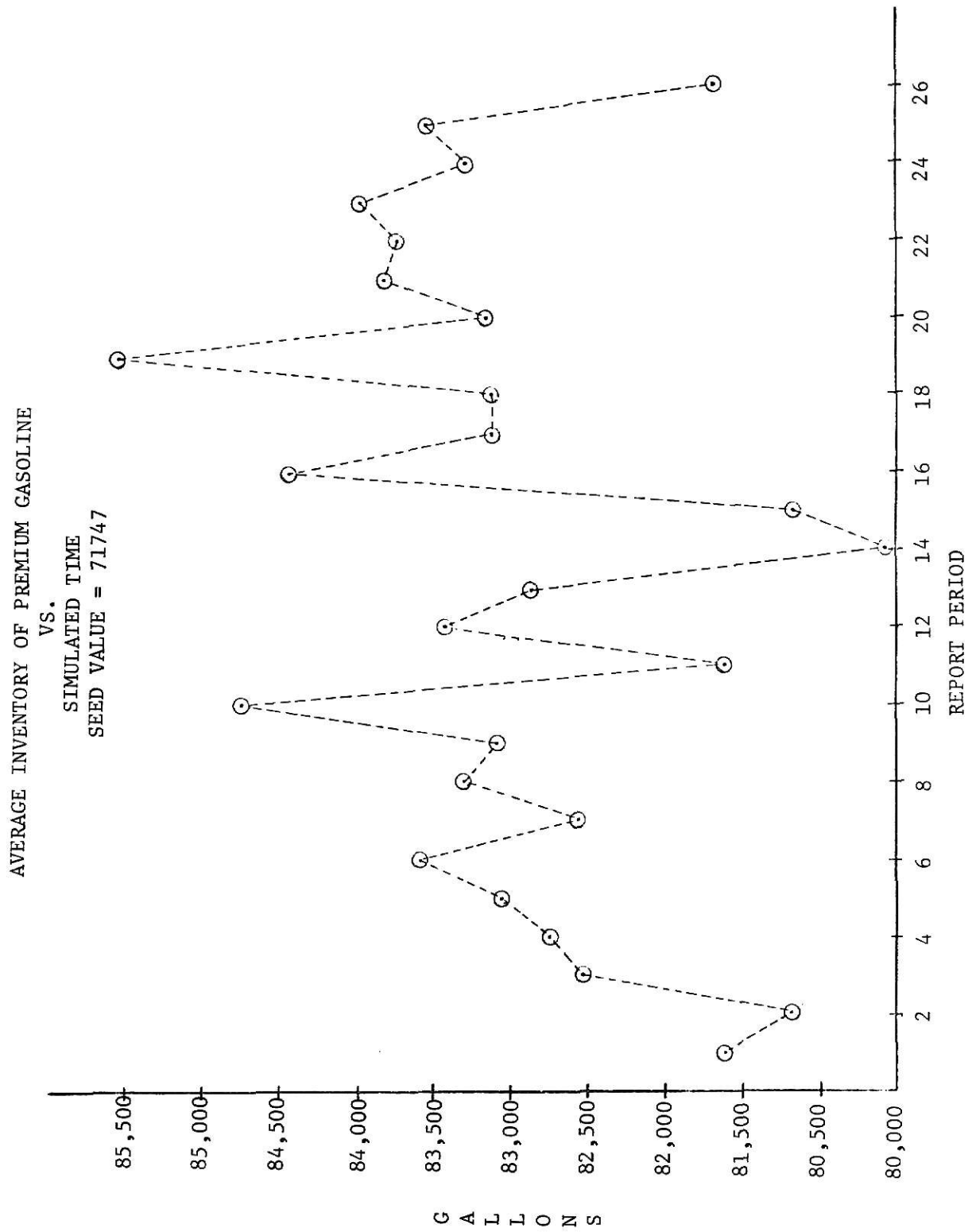


FIGURE 4.7

AVERAGE INVENTORY OF PREMIUM GASOLINE
VS.
SIMULATED TIME
SEED VALUE = 10001

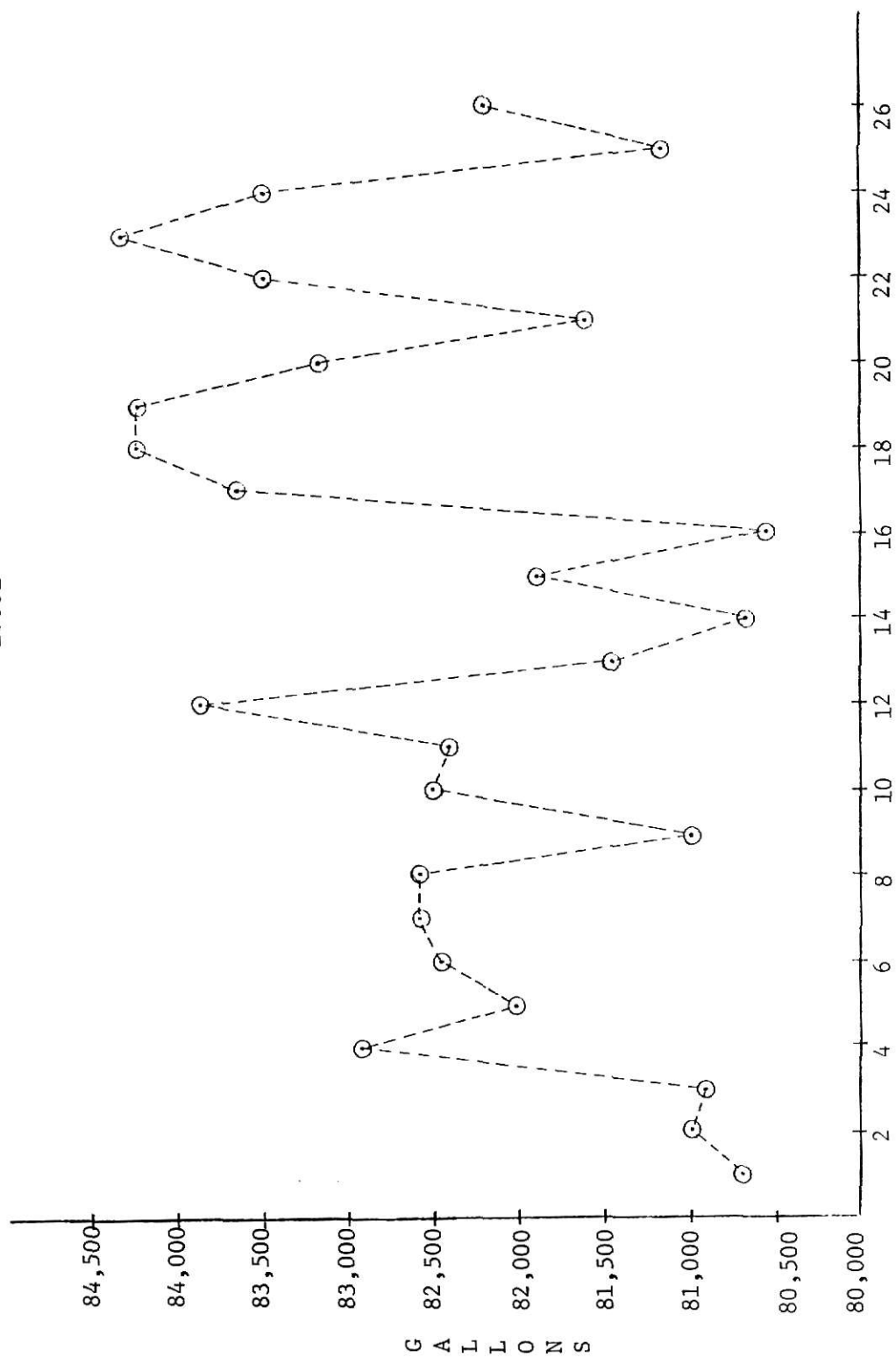


FIGURE 4.8

TOTAL COST VS. SIMULATED TIME
SEED VALUE = 71747

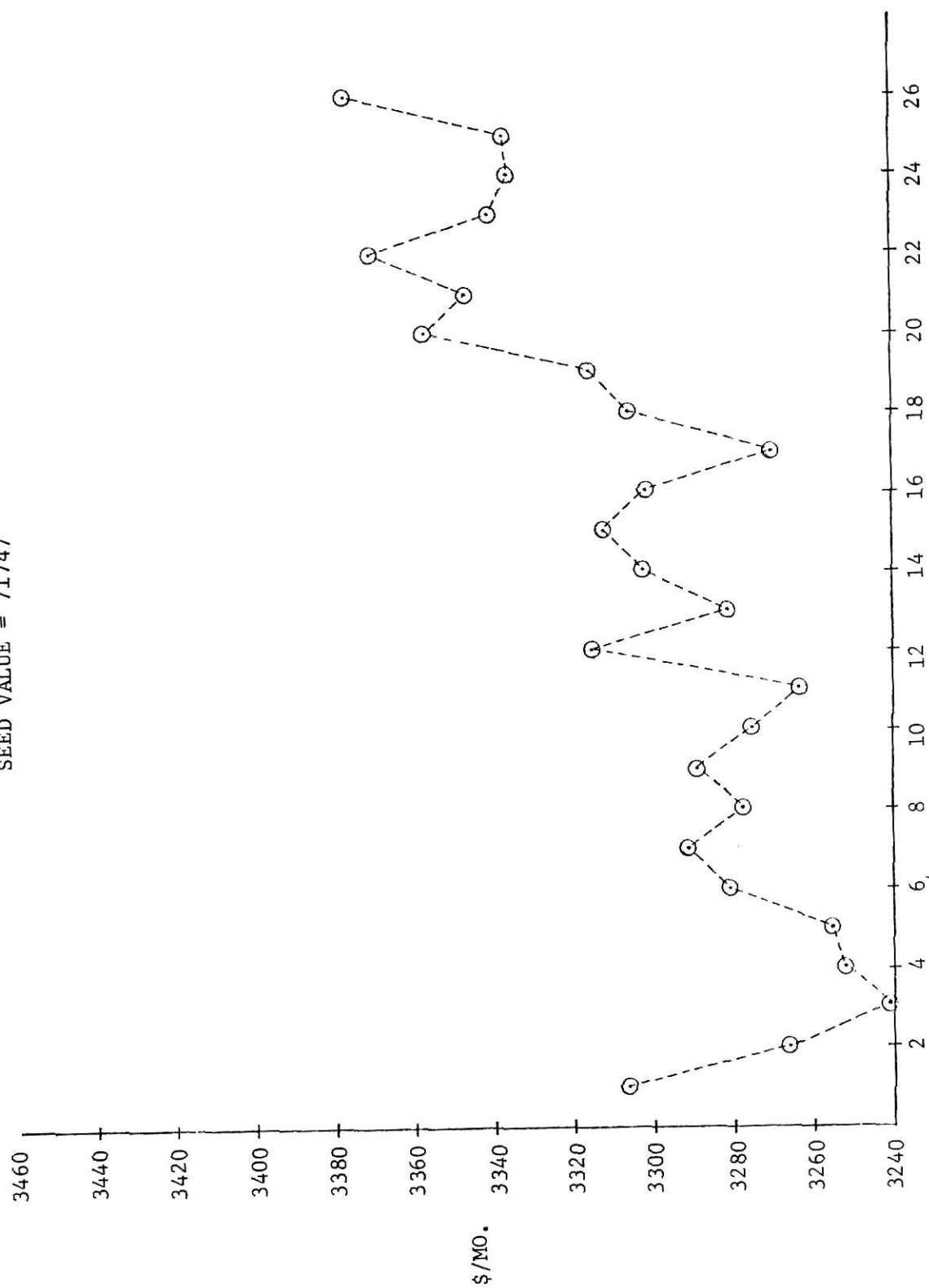


FIGURE 4.9

TOTAL COST VS. SIMULATED TIME
SEED VALUE = 10001

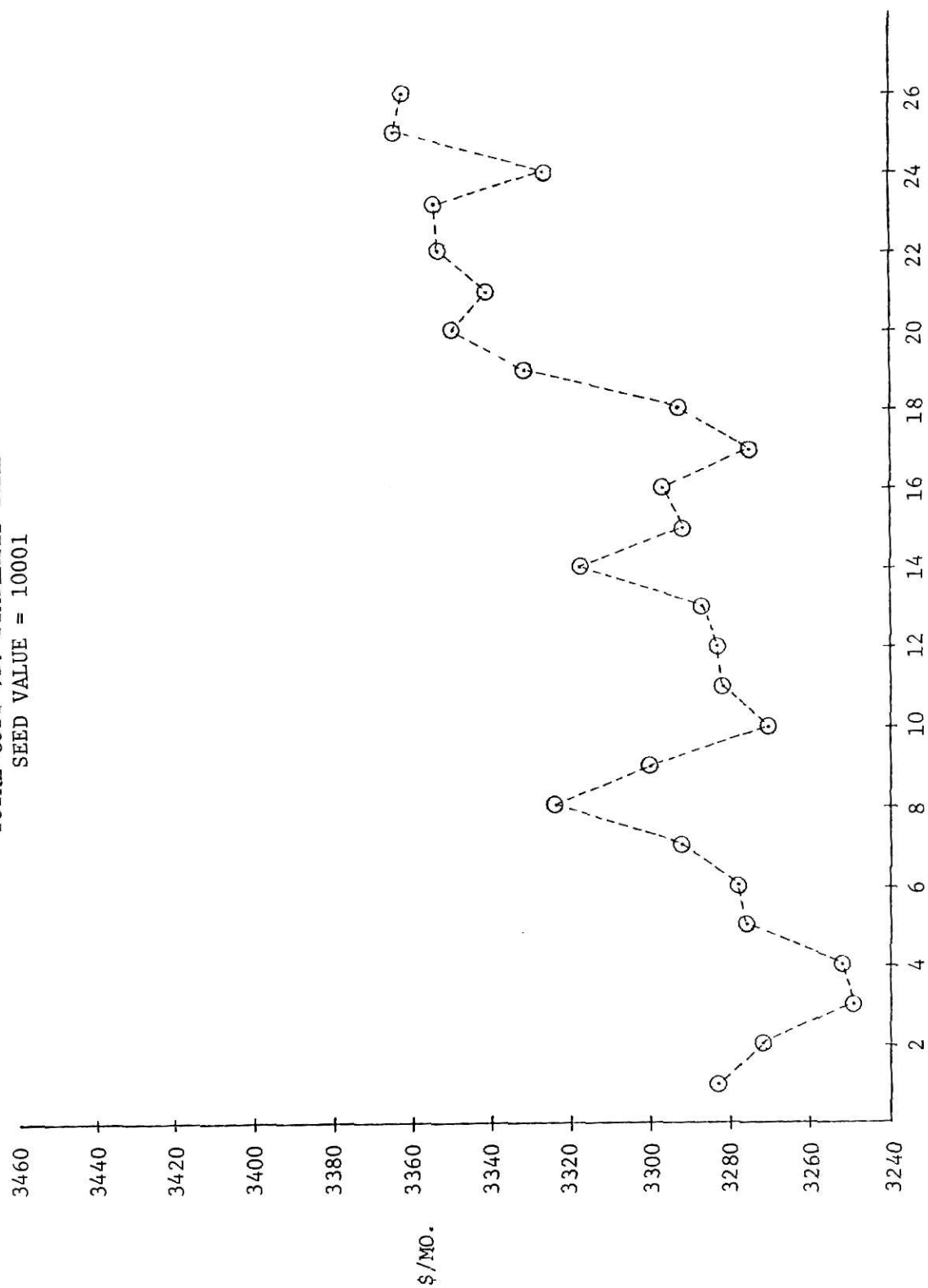


FIGURE 4.10

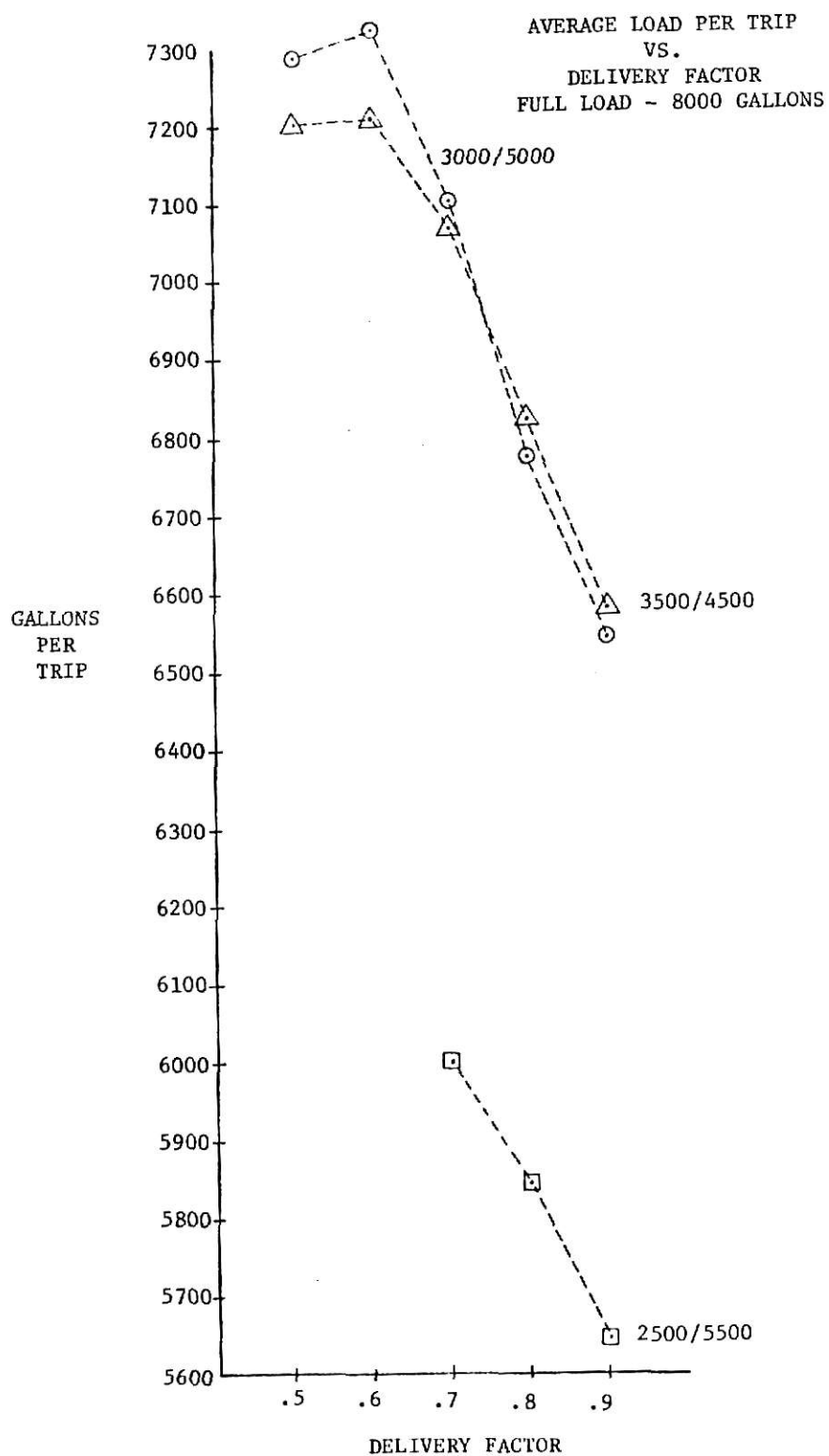


FIGURE 4.11

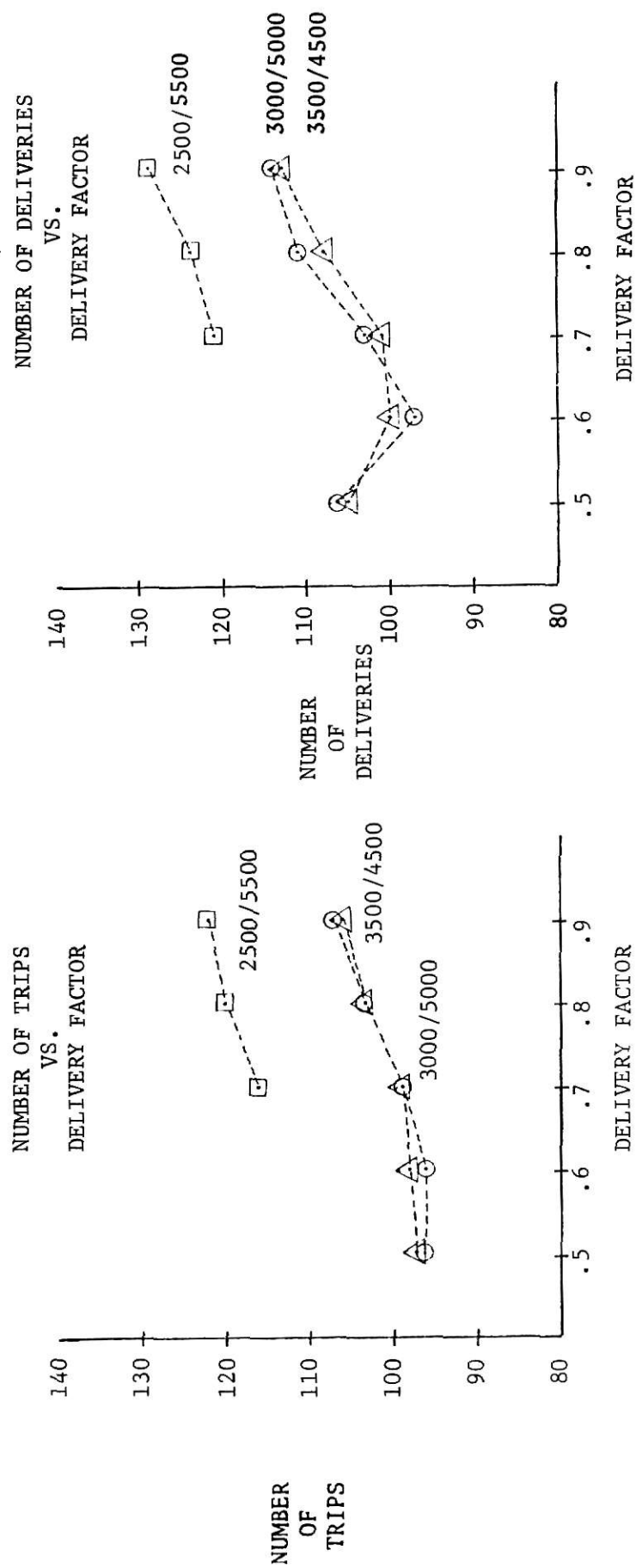


FIGURE 4.12

AVERAGE REGULAR DELIVERY SIZE
VS.
DELIVERY FACTOR

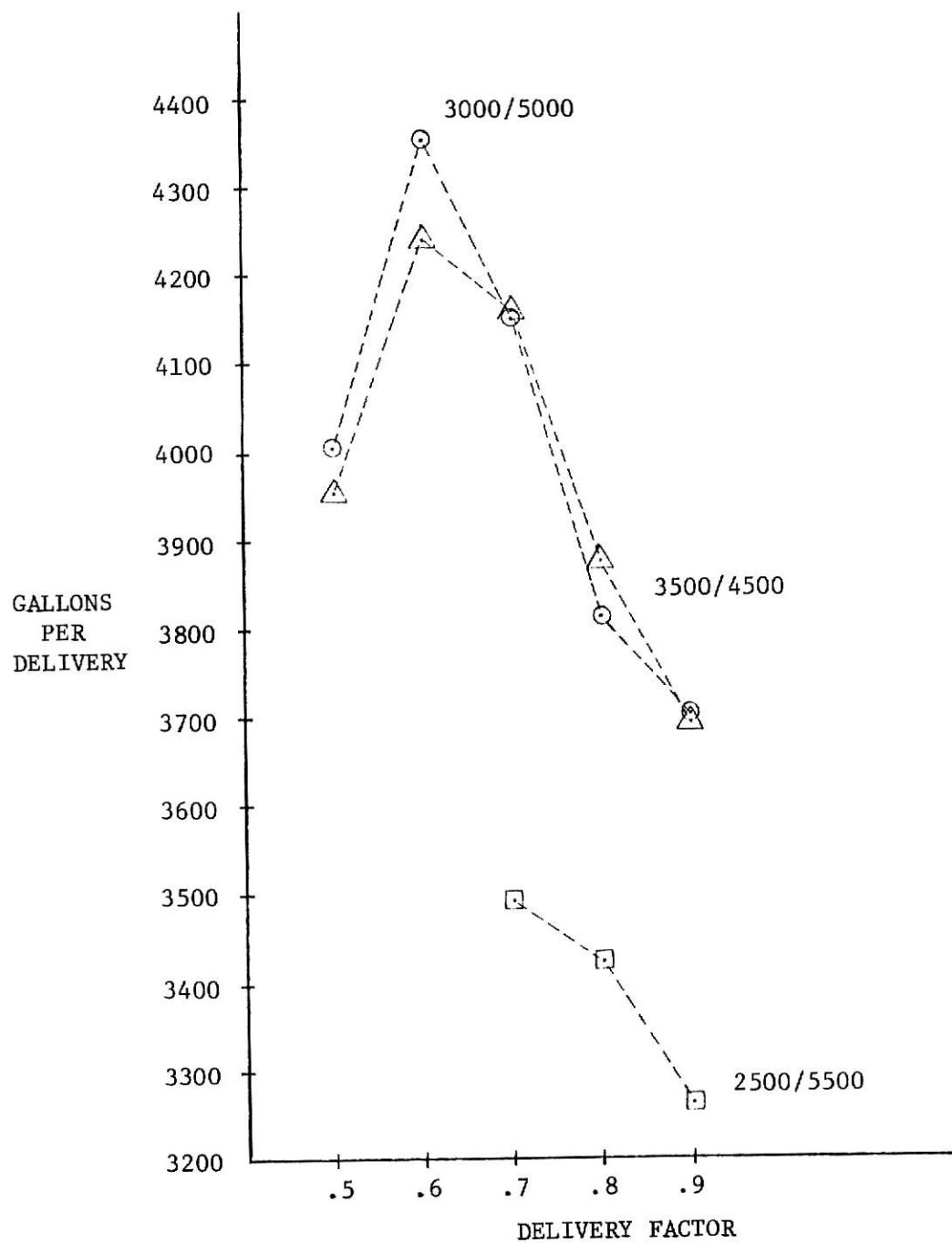


FIGURE 4.13

AVERAGE PREMIUM DELIVERY SIZE
VS.
DELIVERY FACTOR

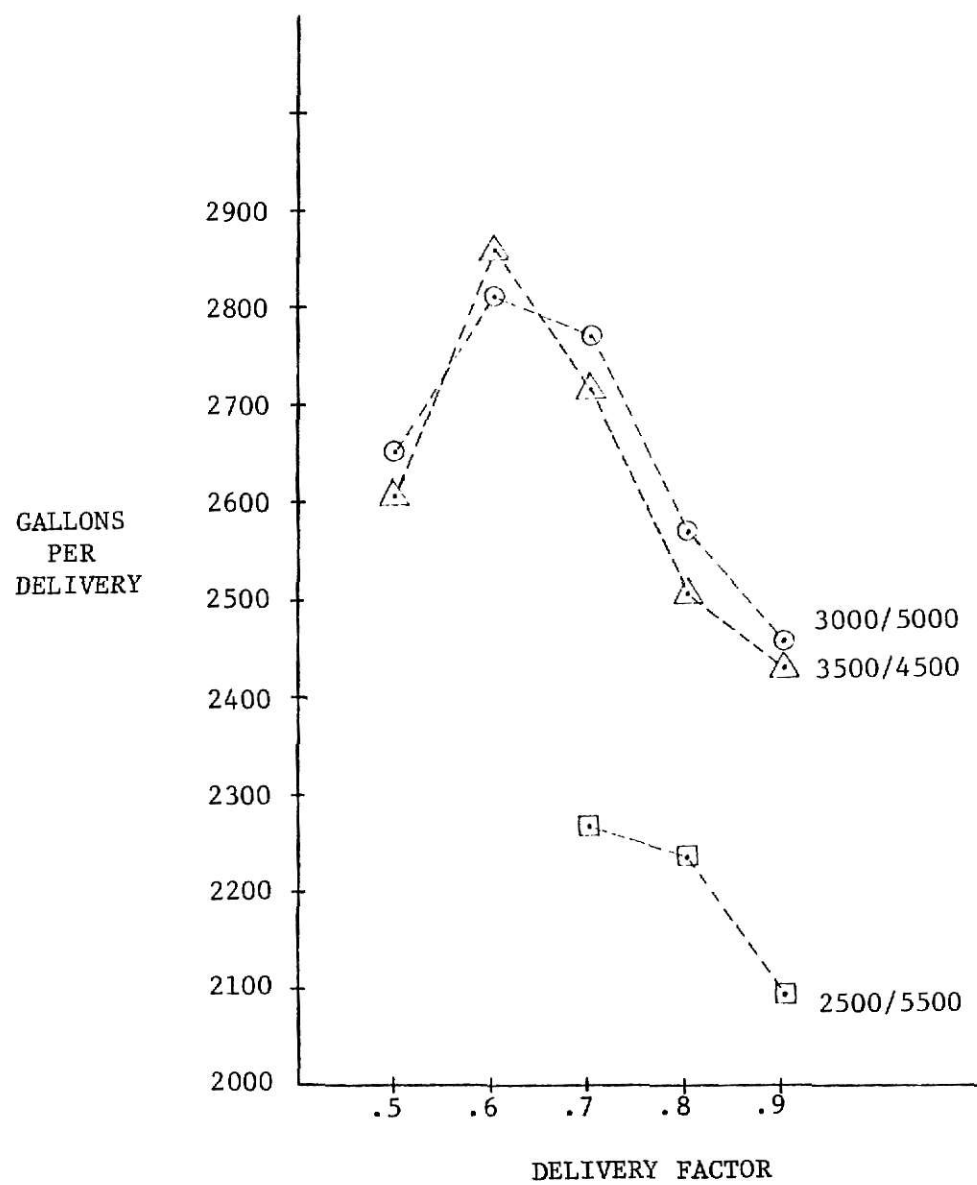


FIGURE 4.14

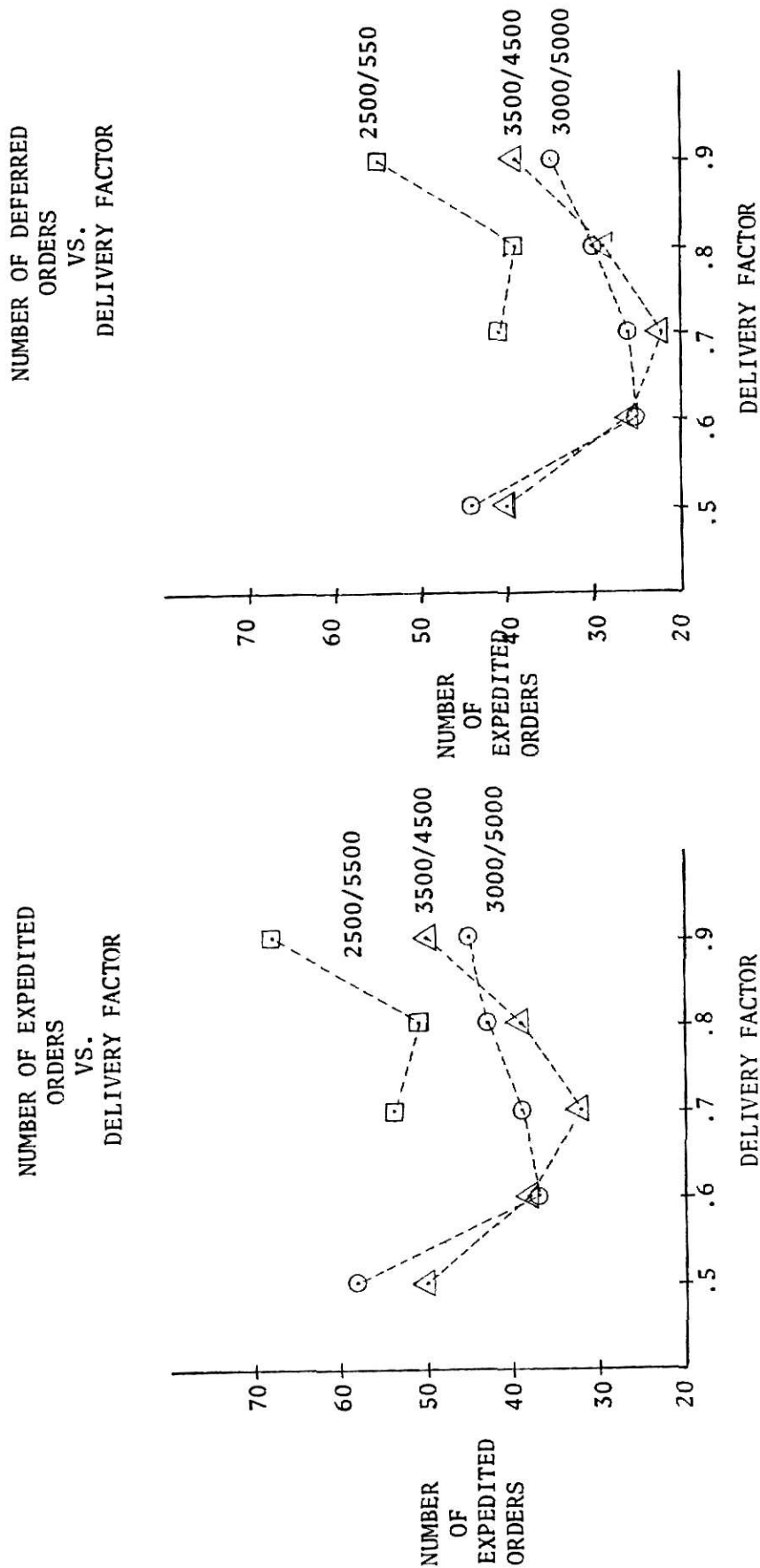


FIGURE 4.15

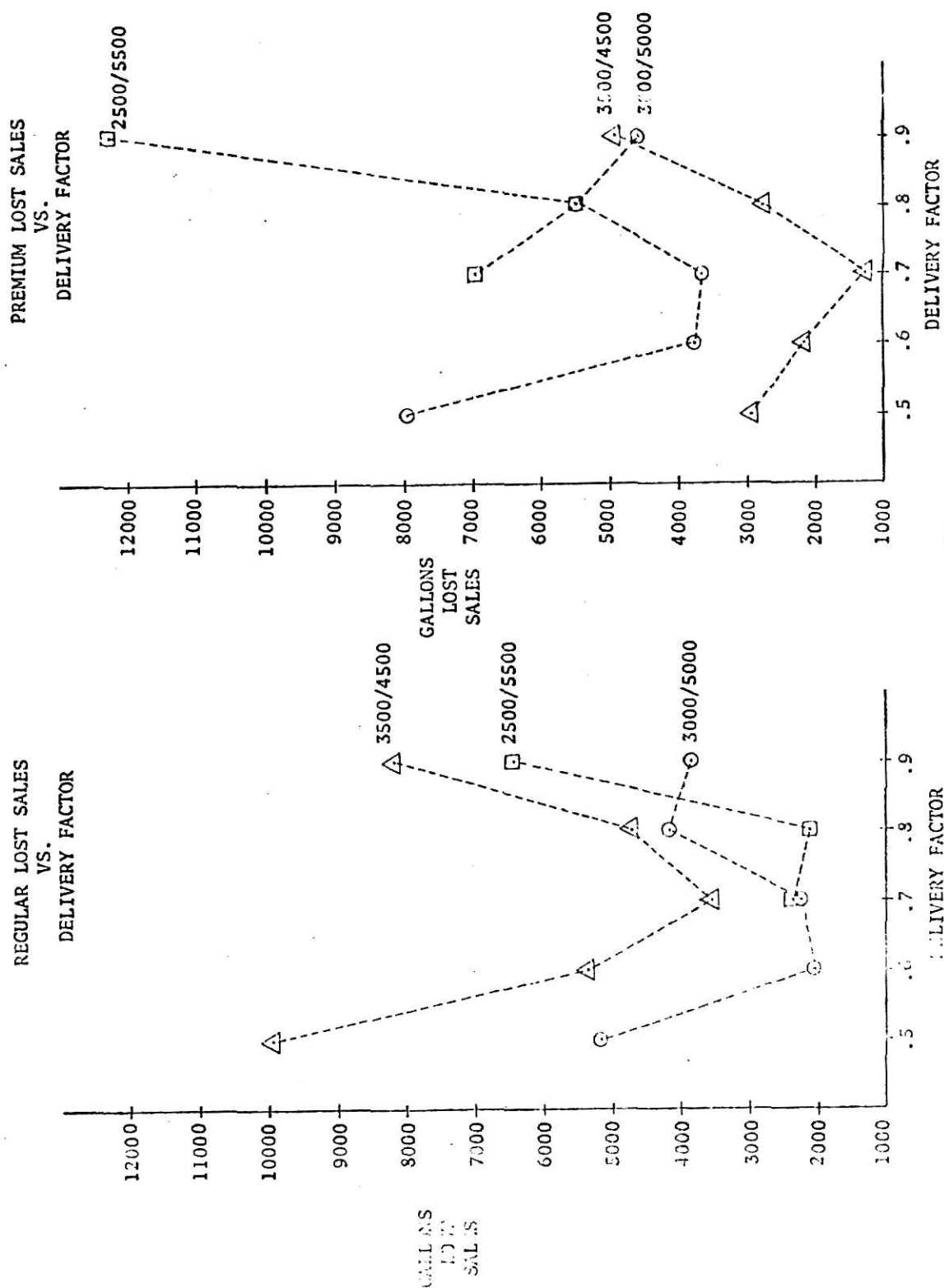


FIGURE 4.16

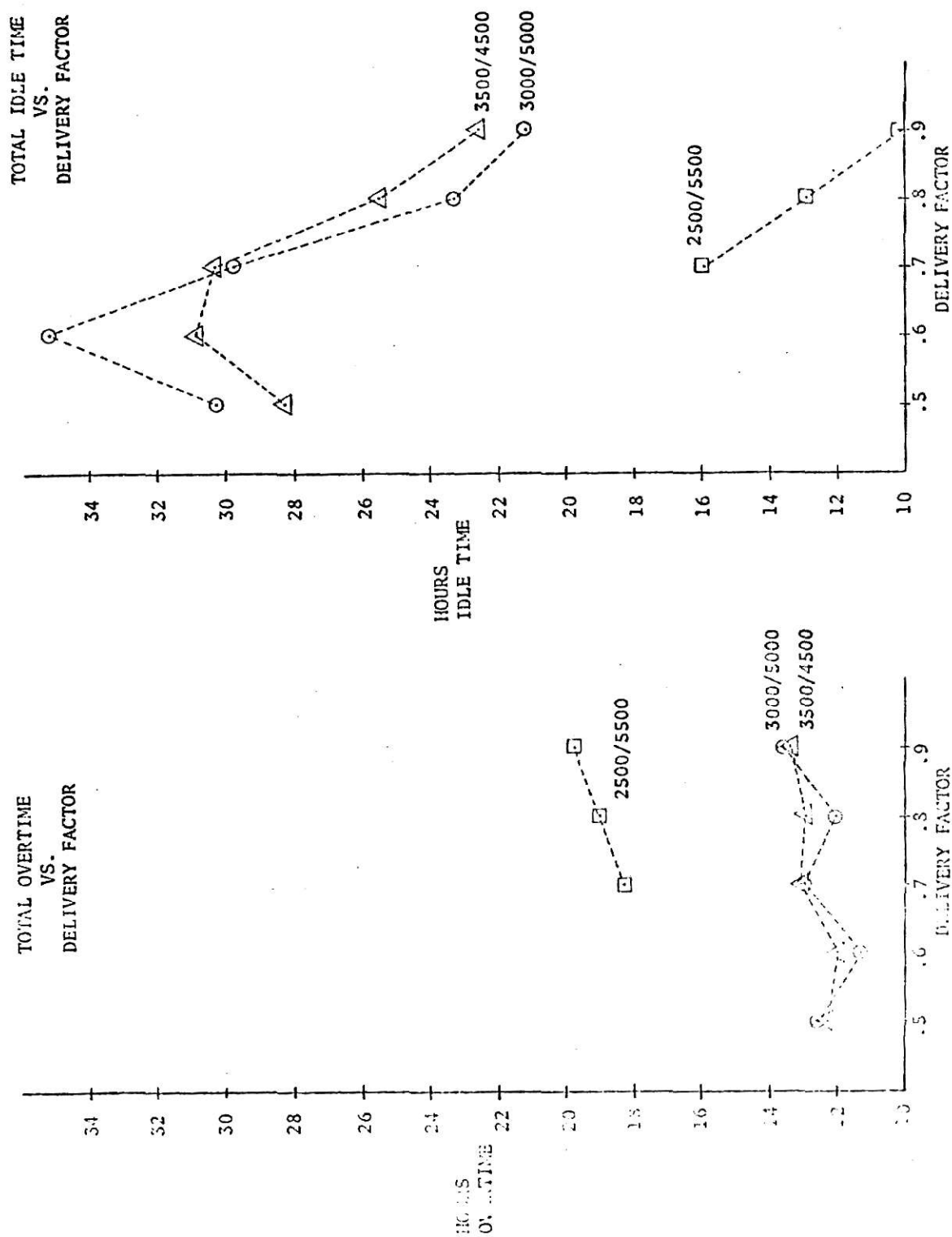


FIGURE 4.17

TOTAL COST VS. DELIVERY FACTOR

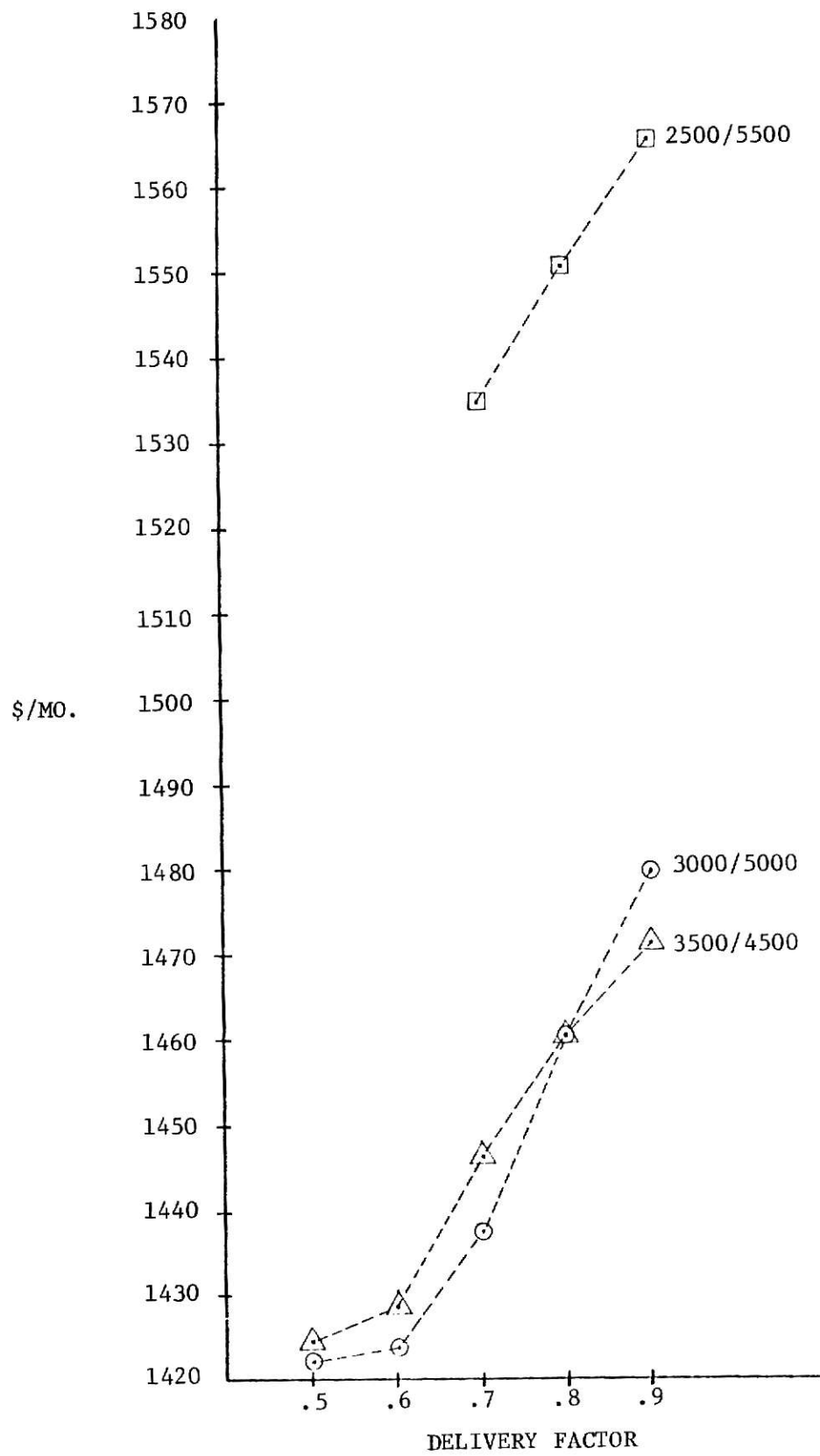


FIGURE 4.18

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Appendix A

Correlation Program

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C001      DOUBLE PRECISION S(2,2), AM(2), X(750,2)
C002      NREAD=5
C003      NWRITE=6
C004      READ(NREAD,900) NPROB
C005      900 FORMAT(I3)
C006      WRITE(NWRITE,930)
C007      930 FORMAT('CORRELATION BETWEEN REGULAR AND PREMIUM GASOLINE SALES'
1)
C008      DO 100 I=1,NPROB
C009      READ(NREAD,900) NCBS
C010      DO 110 J=1,2
C011      110 READ(NREAD,910)(X(JX,J),JX=1,NCBS)
C012      910 FORMAT(15F5.0,5X)
C013      DO 200 JJ=1,NCBS
C014      FI=J
C015      FRC=(FI-1.0)/FI
C016      IF (J .EQ. 1) GO TO 120
C017      GO TO 130
C018      120 DO 125 JJ=1,2
C019      AM(JJ)=X(J,JJ)
C020      DO 123 KK=1,2
C021      123 S(JJ,KK)=0.0
C022      125 CONTINUE
C023      GO TO 200
C024      130 DO 140 JX=1,2
C025      DO 140 K=1,2
C026      140 S(JX,K)=S(JX,K)+FRC*(X(J,JX)-AM(J))*(X(J,K)-AM(K))
C027      DO 150 JX=1,2
C028      150 AM(JX)=FRC*AM(JX)+X(J,JX)/FI
C029      200 CONTINUE
C030      R=S(1,2)/(S(1,1)*S(2,2))*.5
C031      NI=I+15
C032      WRITE(NWRITE,920) NI,R
C033      920 FORMAT('STATION ',I2,5X,' R = ',F7.5)
C034      100 CONTINUE
C035      STOP
C036      END

```

Stratification Program

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C001	COMMON PLT(1500)	KFS00000
C002	NREAD=1	KFS00010
C003	NWRIT=3	KFS00020
C004	READ(NREAD,9000) NDS	KFS00030
C005	DO 10 J=1,NDS	KFS00040
C006	DO 10 I=1,2	KFS00050
C007	READ(NREAD,9000) ND, NTYP, NSTAT	KFS00060
C008	9000 FORMAT(3I5)	KFS00070
C009	READ(NREAD,9010) (PLT(ND+K),K=1,ND)	KFS00080
C010	9010 FORMAT(15F5.0,5X)	KFS00090
C011	CALL STRAT(ND,NREAD,NWRIT,NTYP,NSTAT)	KFS00100
C012	CALL PLOT(PLT,ND,2,ND,C)	KFS00110
C013	10 CONTINUE	KFS00120
C014	STOP	KFS00130
C015	END	KFS00140

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C001      SUBROUTINE STRAT(ND,NREAD,NWRIT,NTYP,NSTAT)      KFS00150
C002      COMMON PLT(1500)      KFS00160
C003      DIMENSION AM(15), SS(15), FI(15), SC(15)      KFS00170
C004      ND $\times$ =ND-7      KFS00180
C005      DO 10 J=1,7      KFS00190
C006      AM(J)=PLT(ND+J)      KFS00200
C007      SS(J)=0.0      KFS00210
C008      10 CONTINUE      KFS00220
C009      AM(8)=AM(6)      KFS00230
C010      AM(9)=AM(1)      KFS00240
C011      SS(8)=0.0      KFS00250
C012      SS(9)=0.0      KFS00260
C013      FI(1)=2.      KFS00270
C014      FI(2)=2.      KFS00280
C015      FI(3)=2.      KFS00290
C016      FI(4)=2.      KFS00300
C017      DO 15 JD=2,5      KFS00310
C018      FRC2=(FI(2)-1.)/FI(2)      KFS00320
C019      SS(9)=SS(9)+FRC2*(PLT(ND+JD)-AM(9))*(PLT(ND+JD)-AM(9))      KFS00330
C020      AM(9)=AM(9)+FRC2*PLT(ND+JD)/FI(2)      KFS00340
C021      15 FI(2)=FI(2)+1.      KFS00350
C022      FRC3=(FI(3)-1.)/FI(3)      KFS00360
C023      SS(8)=SS(8)+FRC3*(PLT(ND+7)-AM(8))*(PLT(ND+7)-AM(8))      KFS00370
C024      AM(8)=AM(8)+FRC3*PLT(ND+7)/FI(3)      KFS00380
C025      FI(3)=FI(3)+1.      KFS00390
C026      DO 50 J=7,ND $\times$ ,7      KFS00400
C027      FRC1=(FI(1)-1.)/FI(1)      KFS00410
C028      DO 20 JD=1,7      KFS00420
C029      SS(JD)=SS(JD)+FRC1*(PLT(ND+J+JD)-AM(JD))*(PLT(ND+J+JD)-AM(JD))      KFS00430
C030      20 AM(JD)=FRC1*AM(JD)+PLT(ND+J+JD)/FI(1)      KFS00440
C031      DO 30 JD=1,5      KFS00450
C032      FRC2=(FI(2)-1.)/FI(2)      KFS00460
C033      SS(9)=SS(9)+FRC2*(PLT(ND+J+JD)-AM(9))*(PLT(ND+J+JD)-AM(9))      KFS00470
C034      AM(9)=AM(9)+FRC2*PLT(ND+J+JD)/FI(2)      KFS00480
C035      30 FI(2)=FI(2)+1.      KFS00490
C036      DO 40 JD=6,7      KFS00500
C037      FRC3=(FI(3)-1.)/FI(3)      KFS00510
C038      SS(8)=SS(8)+FRC3*(PLT(ND+J+JD)-AM(8))*(PLT(ND+J+JD)-AM(8))      KFS00520
C039      AM(8)=AM(8)+FRC3*PLT(ND+J+JD)/FI(3)      KFS00530
C040      40 FI(3)=FI(3)+1.      KFS00540
C041      50 FI(1)=FI(1)+1.      KFS00550
C042      AM(10)=PLT(ND+1)      KFS00560
C043      SS(10)=0.0      KFS00570
C044      FI(4)=2      KFS00580
C045      AM(11)=PLT(ND+159)      KFS00590
C046      SS(11)=0.0      KFS00600
C047      FI(5)=2      KFS00610
C048      DO 100 JIN=1,2      KFS00620
C049      IND=365*(JIN-1)      KFS00630
C050      I1=2+IND      KFS00640
C051      I2=158+IND      KFS00650
C052      DO 60 J=I1,I2      KFS00660
C053      FRC4=(FI(4)-1.)/FI(4)      KFS00670
C054      SS(10)=SS(10)+FRC4*(PLT(ND+J)-AM(10))*(PLT(ND+J)-AM(10))      KFS00680
C055      AM(10)=AM(10)+FRC4*PLT(ND+J)/FI(4)      KFS00690
C056      60 FI(4)=FI(4)+1.      KFS00700
C057      I3=159+IND      KFS00710
C058      I4=249+IND      KFS00720

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[illegible]

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C001	C	SUBROUTINE PLOT(A,N,M,NL,NS)	KFS01630
C002	C	DIMENSION OUT(101),YPR(11),ANG(9),A(1)	KFS01640
C003	C	2 FORMAT(1H ,F11.4,5H+ ,101A1)	KFS01650
C004	C	4 FORMAT(10H *+C156789)	KFS01660
C005	C	5 FORMAT(10A1)	KFS01670
C006	C	7 FORMAT(1H ,16X,101H.)	KFS01680
C007	C	1 .	KFS01690
	C	8 FORMAT(1H0,9X,11F10.4//)	KFS01700
	C		KFS01710
C008	C	NLL=NL	KFS01720
C009	C	IF(NS)16,16,10	KFS01730
	C		KFS01740
	C	SORT BASE VARIABLE IN ASCENDING ORDER	KFS01750
	C		KFS01760
C010	C	10 DO 15 I=1,N	KFS01770
C011	C	DO 14 J=1,N	KFS01780
C012	C	IF(A(I)-A(J))14,14,11	KFS01790
C013	C	11 L=I-N	KFS01800
C014	C	LL=J-N	KFS01810
C015	C	DO 12 K=1,M	KFS01820
C016	C	L=L+N	KFS01830
C017	C	LL=LL+N	KFS01840
C018	C	F=A(L)	KFS01850
C019	C	A(L)=A(LL)	KFS01860
C020	C	12 A(LL)=F	KFS01870
C021	C	14 CONTINUE	KFS01880
C022	C	15 CONTINUE	KFS01890
	C		KFS01900
	C	TEST NLL	KFS01910
	C		KFS01920
C023	C	16 IF(NLL)20,18,20	KFS01930
C024	C	18 NLL=50	KFS01940
C025	C	20 CONTINUE	KFS01950
	C		KFS01960
	C	DEVELOP BLANKS AND DIGITS FOR PRINTING	KFS01970
	C		KFS01980
C026	C	REWIND 10	KFS01990
C027	C	WRITE(10,4)	KFS02000
C028	C	REWIND 10	KFS02010
C029	C	READ(10,5)BLANK,(ANG(I),I=1,9)	KFS02020
C030	C	REWIND 10	KFS02030
	C		KFS02040
	C	FIND SCALE FOR BASE VARIABLE	KFS02050
	C		KFS02060
C031	C	XSCALE=(A(N)-A(1))/(FLOAT(NLL-1))	KFS02070
	C		KFS02080
	C	FIND SCALE FOR CROSS VARIABLES	KFS02090
	C		KFS02100
C032	C	M1=N+1	KFS02110
C033	C	YMIN=A(M1)	KFS02120
C034	C	YMAX=YMIN	KFS02130
C035	C	M2=M*N	KFS02140
C036	C	DO 40 J=M1,M2	KFS02150

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C037	IF(A(IJ)-YMIN)28,28,26	KFS02210
C038	26 IF(A(IJ)-YMAX)40,40,30	KFS02220
C039	28 YMIN=A(IJ)	KFS02230
C040	GO TO 40	KFS02240
C041	30 YMAX=A(IJ)	KFS02250
C042	40 CONTINUE	KFS02260
C043	YSCAL=(YMAX-YMIN)/100.0	KFS02270
C		KFS02280
C	FIND BASE VARIABLE PRINT POSITION	KFS02290
C		KFS02300
C044	XB=A(1)	KFS02310
C045	L=1	KFS02320
C046	MY=M-1	KFS02330
C047	I=1	KFS02340
C048	45 F=I-1	KFS02350
C049	XPR=XB+F*XSCAL	KFS02360
C		KFS02370
C	FIND CRSS VARIABLES	KFS02380
C		KFS02390
C050	51 DO 55 IX=1,101	KFS02400
C051	55 CUT(IX)=BLANK	KFS02410
C052	57 DO 60 J=1,MY	KFS02420
C053	LL=L+J*N	KFS02430
C054	JP=((A(LL)-YMIN)/YSCAL)+1.0	KFS02440
C055	CUT(JP)=ANG(J)	KFS02450
C056	60 CONTINUE	KFS02460
C		KFS02470
C	PRINT LINE AND CLEAR, OR SKIP	KFS02480
C		KFS02490
C057	WRITE(3,2)XPR,(CUT(IZ),IZ=1,101)	KFS02500
C058	L=L+1	KFS02510
C059	80 I=I+1	KFS02520
C060	IF(I-NLL)45,84,86	KFS02530
C061	84 XPR=A(N)	KFS02540
C062	GO TO 51	KFS02550
C		KFS02560
C	PRINT CRSS VARIABLES NUMBERS	KFS02570
C		KFS02580
C063	80 WRITE(3,7)	KFS02590
C064	YPR(1)=YMIN	KFS02600
C065	DO 90 KN=1,9	KFS02610
C066	90 YPR(KN+1)=YPR(KN)+YSCAL*10.0	KFS02620
C067	YPR(11)=YMAX	KFS02630
C068	WRITE(3,8)(YPR(IR),IR=1,11)	KFS02640
C069	RETURN	KFS02650
C070	END	KFS02660

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
C      DIMENSION S(12,12), AM(12), SS(12,12), A(750), MM(12), L(12), B(12) KFS00000
1) , R(12), SST(12,12), RESID(750) KFS00010
COMMON X(750,12) KFS00020
PI=3.1415927 KFS00030
READ(1,200) NM,N,NPLT,NLAG,IW,NSTAT,NTYP,DW KFS00040
200 FORMAT(7I5,F5.3) KFS00050
IF (NTYP .EQ. 2) GO TO 1000 KFS00060
WRITE (3,1010) NSTAT KFS00070
1010 FORMAT(47X,' REGULAR GRADE GASOLINE - STATION ',I3, '/') KFS00080
GO TO 1030 KFS00090
1000 WRITE(3,1020) NSTAT KFS00100
1020 FORMAT(47X,' PREMIUM GRADE GASOLINE - STATION ',I3, '/') KFS00110
1030 CONTINUE KFS00120
WRITE(3,210) NM,N KFS00130
210 FORMAT(' NUMBER OF VARIABLES = ',I2,' NUMBER OF DATA POINTS =',I3) KFS00140
READ(1,152)(X(I,NM),I=1,N) KFS00150
152 FORMAT(15F5.0,5X) KFS00160
WRITE(3,230) KFS00170
C 230 FORMAT('/', ' ECHO CHECK OF INPUT DATA '/') KFS00180
C WRITE(3,240)(X(I,NM),I=1,N) KFS00190
C 240 FORMAT(1H ,12F8.2) KFS00200
C KFS00210
C TRANSFORMATIONS ON INDEPENDENT VARIABLES KFS00220
C KFS00230
C CALL DATX(N) KFS00240
C KFS00250
DO 190 I=1,N KFS00260
FI=I KFS00270
FRC=(FI-1.0)/FI KFS00280
IF (I .EQ. 1) GO TO 153 KFS00290
GO TO 155 KFS00300
153 DO 154 JJ=1,NM KFS00310
AM(JJ)=X(I,JJ) KFS00320
DO 149 KK=1,NM KFS00330
149 S(JJ,KK)=0.0 KFS00340
154 CONTINUE KFS00350
GO TO 190 KFS00360
155 DO 151 J=1,NM KFS00370
DO 151 K=1,NM KFS00380
S(J,K)=S(J,K)+FRC*(X(I,J)-AM(J))*(X(I,K)-AM(K)) KFS00390
151 CONTINUE KFS00400
DO 156 J=1,NM KFS00410
AM(J)=FRC*AM(J)+X(I,J)/FI KFS00420
156 CONTINUE KFS00430
190 CONTINUE KFS00440
WRITE(3,250) KFS00450
250 FORMAT('/', ' MEANS OF INPUT VARIABLES '/') KFS00460
DO 260 I=1,NM KFS00470
260 WRITE(3,270) I,AM(I) KFS00480
270 FORMAT(' MEAN OF X(',I2,')=',F11.6) KFS00490
M=NM-1 KFS00500
C X*X MATRIX KFS00510
WRITE(3,280) KFS00520
280 FORMAT('/', ' X PRIME X MATRIX ', '/') KFS00530
DO 157 J=1,M KFS00540
WRITE(3,158) (S(J,K),K=1,M) KFS00550
158 FORMAT(1H ,8F15.6) KFS00560

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```

157 CONTINUE
C   NORMALIZATION
    WRITE(3,290)
290  FORMAT(///,' CORRELATION MATRIX ',//)
    DO 161 J=1,M
    DO 160 K=1,M
160  SS(J,K)=S(J,K)/(IS(J,J)*S(K,K))**0.5
161  WRITE(3,158) (SS(J,K),K=1,M)
    DO 163 J=1,M
    DO 163 KK=1,M
    I=(J-1)*M+KK
163  A(I)=SS(J,KK)
    CALL MINV(A,M,D,L,MM)
    MMM=M*M
    DO 600 I=1,MMM
    JJ=(I+M-1)/M
    II=I-(JJ-1)*M
600  SST(II,JJ)=A(I)
    WRITE(3,610)
610  FORMAT(///,' CORRELATION MATRIX INVERSE ',//)
    DO 620 I=1,M
620  WRITE(3,630) (SST(I,J),J=1,M)
630  FORMAT(8F15.6)
    WRITE(3,310) D
310  FORMAT(/,' DETERMINANT = ',E14.6)
    WRITE(3,300)
300  FORMAT(///,' X PRIME Y MATRIX ',//)
    DO 164 J=1,M
    B(J)=S(J,NM)/(S(J,J)*S(NM,NM))**0.5
164  WRITE(3,158) B(J)
    LL=1
    MSA=0
    MSB=0
    CALL MPRD(A,B,R,M,M,MSA,MSB,LL)
C
C   CALCULATE SUM OF SQUARES FROM REGRESSION
C
    CALL MPRG(R,B,SSQP,1,M,0,0,1)
    WRITE(3,305)
305  FORMAT(/,' BETAS FROM CENTERED DATA ',//)
    DO 170 J=1,M
170  WRITE(3,159) J, R(J)
159  FORMAT(' B(',12,') = ',F15.6)
    XLN=0.0
    DO 175 ICX=1,M
175  XLN=(R(ICX)**2)+XLN
    XLN=XLN**0.5
    WRITE(3,330) XLN
330  FORMAT(/,' LENGTH OF BETA VECTOR = ',E14.6)
C   CONVERT BETA VECTOR
    DO 180 ICX=1,M
180  R(ICX)=R(ICX)*(S(NM,NM)/S(ICX,ICX))**0.5
    RZO=AM(NM)
    DO 197 IUX=1,M
197  RZO=RZO-R(ICX)*AM(ICX)
    WRITE(3,340)
340  FORMAT(/,' ESTIMATES OF BETAS INCLUDING INTERCEPT TERM ',//)
    WRITE(3,350) RZO
350  FORMAT(' B( 0) = ',F15.6)
    DO 195 IDX=1,M

```

KFS00580
 KFS00590
 KFS00600
 KFS00610
 KFS00620
 KFS00630
 KFS00640
 KFS00650
 KFS00660
 KFS00670
 KFS00680
 KFS00690
 KFS00700
 KFS00710
 KFS00720
 KFS00730
 KFS00740
 KFS00750
 KFS00760
 KFS00770
 KFS00780
 KFS00790
 KFS00800
 KFS00810
 KFS00820
 KFS00830
 KFS00840
 KFS00850
 KFS00860
 KFS00870
 KFS00880
 KFS00890
 KFS00900
 KFS00910
 KFS00920
 KFS00930
 KFS00940
 KFS00950
 KFS00960
 KFS00970
 KFS00980
 KFS00990
 KFS01000
 KFS01010
 KFS01020
 KFS01030
 KFS01040
 KFS01050
 KFS01060
 KFS01070
 KFS01080
 KFS01090
 KFS01100
 KFS01110
 KFS01120
 KFS01130
 KFS01140
 KFS01150
 KFS01160
 KFS01170


```

195 WRITE(3,360) IDX,R(IDX)
360 FORMAT(' B(',I2,') = ',F15.6)
C
C      ANALYSIS OF VARIANCE
C
      WRITE(3,700)
700 FORMAT(///,40X,' ANALYSIS OF VARIANCE TABLE ')
      WRITE(3,705)
705 FORMAT(39X,' ( IN TERMS OF CORRELATIONS ) ')
      WRITE(3,710)
710 FORMAT(//,7X,' SOURCE ',15X,' SUM OF SQUARES ',15X,' DEGREES OF FREEDOM ',15X,' MEAN SQUARE ')
      NDF3=NM-1
      XNDF3=NM-1
      S1=SSQR/XNDF3
      WRITE(3,720) SSQR,NDF3,S1
720 FORMAT(/,5X,' REGRESSION ',14X,F15.6,23X,I2,23X,F15.6)
      SSAR=1.00-SSQR
      TOTAL=1.00
      NDF1=N-1
      NDF2=N-NM
      XNDF2=NDF2
      S2=SSAR/XNDF2
      FRAT=S1/S2
      R2=SSQR
      WRITE(3,730) SSAR,NDF2,S2
730 FORMAT(5X,' RESIDUAL ',16X,F15.6,22X,I3,23X,F15.6)
      WRITE(3,740) TOTAL,NDF1
740 FORMAT(5X,' TOTAL ',19X,F15.6,22X,I3)
      WRITE(3,750) FRAT
750 FORMAT(//,5X,' CALCULATED F RATIO = ',F15.6)
      WRITE(3,760) R2
760 FORMAT(//,5X,' RSC = ',F15.6)
C
C      BACK CALCULATION
C
      WRITE(3,810)
C 810 FORMAT(///,35X,' BACK CALCULATIONS ',//)
      WRITE(3,820)
C 820 FORMAT(/,5X,' OBSERVATION',8X,' Y OBSERVED ',7X,' Y CALCULATED ',9X)
C 1X,' RESIDUAL ',//)
      RESSQ=0.0
      RSME=0.0
      DO 800 I=1,N
        YCALC=RZC
      DO 805 J=1,M
        YCALC=YCALC+X(I,J)*R(J)
      805 RESID(I)=YCALC-X(I,NM)
      RESSQ=RESSQ+RESID(I)*RESID(I)
      RSME=RSME+RESID(I)
      800 CONTINUE
C 800 WRITE(3,830) I,X(I,NM),YCALC,RESID(I)
C 830 FORMAT(11X,I3,9X,F15.6,5X,F15.6,5X,F15.6)
      WRITE(3,840) RESSQ
840 FORMAT(/,5X,' SUM OF SQUARES OF ERRORS = ',F15.6)
      REALN=N
      RSMEAN=RSME/REALN
      RSSTD=((1/REALN)*(REALN*RESSQ-RSME*RSME))**.5
      WRITE(3,900) RSMEAN,RSSTD
900 FORMAT(/,5X,' MEAN OF ERRORS = ',F15.6,5X,' STANDARD DEVIATION OF

```

```
      IERRORS = 1,F15.6)
165  CONTINUE
      CALL SPLOT(N,RESID,1,DW)
      CALL PARZNI(RESID,N,NPLT,NLAG,IW,DW)
      STOP
      END
```

```
KFS01780
KFS01790
KFS01800
KFS01810
KFS01820
KFS01830
```

C		
C		
	SUBROUTINE DATX(N)	KFS01840
C		
C		
	COMMON X(750,12)	KFS01850
	PI=3.1415927	KFS01860
	DO 10 I=1,N	KFS01870
	FI=I	KFS01880
	X(I,1)=FI	KFS01890
	X(I,2) = COS(2.*PI*FI/7.)	KFS01900
	X(I,3) = SIN(2.*PI*FI/7.)	KFS01910
	X(I,4)=COS(2.*PI*FI/3.5)	KFS01920
	X(I,5)=SIN(2.*PI*FI/3.5)	KFS01930
	X(I,6)=COS(2.*PI*FI/182.5)	KFS01940
	X(I,7)=SIN(2.*PI*FI/182.5)	KFS01950
	X(I,8)=COS(2.*PI*FI/365.)	KFS01960
	X(I,9)=SIN(2.*PI*FI/365.)	KFS01970
	X(I,10)=COS(2.*PI*FI/73.)	KFS01980
	X(I,11)=SIN(2.*PI*FI/73.)	KFS01990
10	CONTINUE	KFS02000
	RETURN	KFS02010
	END	KFS02020

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.

```

C
C
C DIMENSIONED FOR 30. 30 VARIABLES INCLUDE 29 EXPLANATORY AND KFS00000
C ONE DEPENDENT. KFS00010
C THE NUMBER OF OBSERVATIONS IS LIMITED TO 9999, AND MUST EXCEED KFS00020
C THE NUMBER OF VARIABLES BY AT LEAST 2. KFS00030
C THE SPECIFIED INCOMING F LEVEL MUST NOT BE LESS THAN THE SPECIFIED KFS00040
C OUTGOING F LEVEL. KFS00050
C THE VARIABLE FORMAT FOR THE DATA IS READ IN WITH THE CONTROL CARDS KFS00060
C TRANSFORMATIONS ARE PERFORMED IN THE SUBROUTINE TRANS, AND MUST BE KFS00070
C ADDED BY THE USER. SUBROUTINE TRANS MUST BE PRESENT, EVEN IF NO KFS00080
C TRANSFORMATIONS ARE PERFORMED. KFS00090
C CARDS PRECEDING DATA MUST BE THESE, AND MUST OCCUR IN THIS ORDER: KFS00100
C   NUMBER OF PROBLEMS KFS00110
C   HEADING KFS00120
C   PROBLEM PARAMETERS KFS00130
C   VARIABLE NAME DECK KFS00140
C   DATA FORMAT KFS00150
C DESCRIPTION OF THE FORMATS FOR THESE CARDS IS FOUND IN THE KFS00160
C PROGRAM WRITEUP. KFS00170
C THIS PROGRAM ASSUMES THAT VARIABLE NAMES WILL BE USED WITH THE DATA KFS00180
C IF VARIABLE NAMES ARE NOT DESIRED, STATEMENT NO. 91 MUST BE CHANGED KFS00190
C READ NNA=0, AND THE VARIABLE NAMES SHOULD BE EXCLUDED FROM THE DATA KFS00200
C CARDS SPECIFYING THE DEPENDENT VARIABLE FOR EACH REGRESSION MUST KFS00210
C FOLLOW THE DATA. KFS00220
C KFS00230
C KFS00240
C KFS00250
C KFS00260
C KFS00270
C KFS00280
C KFS00290
C KFS00300
C KFS00310
C KFS00320
C KFS00330
C KFS00340
C KFS00350
C KFS00360
C KFS00370
C KFS00380
C KFS00390
C KFS00400
C KFS00410
C KFS00420
C KFS00430
C KFS00440
C KFS00450
C KFS00460
C KFS00470
C KFS00480
C KFS00490
C KFS00500
C KFS00510
C KFS00520
C KFS00530
C KFS00540
C KFS00550
C KFS00560
C KFS00570
C KFS00580
C
C PHASE 1. TRANSFORM ORIGINAL DATA, COMPUTE AND PRINT MEANS,
C STANDARD DEVIATIONS, AND SIMPLE CORRELATION COEFFICIENTS.
C IMPLICIT REAL*8(A-H,O-Y)
C
C DIMENSIONS
C DIMENSION XXBAR(30), SSIGMA(30)
C DIMENSION NAME(30,2), ISAVE(30)
C DIMENSION DATA(30), RRIJ(30,30), FMT(100), DATX(5900)
C DIMENSION RIJ(30,30), XBAR(30), SIGMA(30), A(0(18)
C DIMENSION SIGB(30), B(30), ID(60)
C DIMENSION ZRESID(2)
C
C EQUIVALENCES
C EQUIVALENCE (SIGMA(1),DATA(1))
C
C 1 FORMAT(20A4)
C 2 FORMAT(2I3,I4,I3,2F6.3,I1,I2)
C 3 FORMAT(F10.4,F10.3,3F10.4)
C 4 FORMAT(2A4)
C 5 FORMAT('O VARIABLE NUMBERS AND NAMES')
C 6 FORMAT(6(' ',I3,3X,2A4,5X))
C 7 FORMAT('O STEP NUMBER ',I3,10X,'ENTER VARIABLE ',I3,3X,2A4)
C
C 51 FORMAT('O AVERAGES')
C 52 FORMAT(4(' VAR(',I3,')=' ,F11.4,A1))
C 53 FORMAT('O STANDARD DEVIATIONS')
C 55 FORMAT('O SIMPLE CORRELATION COEFFICIENTS')
C 56 FORMAT(4(' VARS(',I3,',' ,I3,')=' ,F8.5,A1))
C 57 FORMAT('O STEP NUMBER ',I3,10X,'ENTER VARIABLE ',I3)
C 58 FORMAT(' STANDARD ERROR OF ESTIMATE=' ,F12.5)
C 59 FORMAT(' MULTIPLE CORRELATION COEFFICIENT =' ,F8.5)
C 60 FORMAT(' CONSTANT TERM=' ,F12.4)
C 61 FORMAT('OVAR COEFF STD DEV T VALUE BETA COEFF')
C 62 FORMAT(' COEFF')
C 63 FORMAT(' ',I3,F10.4,F12.4,F10.4,F12.4)
C 64 FORMAT('O STEP NUMBER ',I3,10X,'DELETE VARIABLE ',I3)
C 65 FORMAT('I',18A4)

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66 FORMAT(' GOODNESS OF FIT,F(' ,I4,' ',I4,' )= ',F10.4) KFS00590
67 FORMAT('O OBS      ACTUAL      ESTIMATE      RESIDUAL') KFS00600
68 FORMAT(' ',I4,4F12.4) KFS00610
69 FORMAT('SELECTION ',I4,10X,'DEPENDENT VARIABLE ',I4,10X,I4,' INK' KFS00620
    'DEPENDENT VARIABLES') KFS00630
80 FORMAT(1X,'NUMBER OF SELECTIONS NOT SPECIFIED. JOB TERMINATED.') KFS00640
82 FORMAT(1X,'DEGREES OF FREEDOM =0. EITHER ADD MORE DATA OBSERVATION' KFS00650
    'IS OR DELETE ONE OR MORE INDEPENDENT VARIABLES.'/'SAMPLE SIZE MUST KFS00660
    'EXCEED NUMBER OF INDEPENDENT VARIABLES BY AT LEAST TWO.') KFS00670
83 FORMAT(1X,'F LEVEL FOR INCOMING VARIABLE IS LESS THAN F LEVEL FOR KFS00680
    'OUTGOING VARIABLE.') KFS00690
84 FORMAT(40I2) KFS00700
85 FORMAT(1H-,'NORMAL END OF PROGRAM') KFS00710
86 FORMAT(F6.4) KFS00720
C STATEMENT LABEL 101 IS NOT REFERENCED. IT MARKS THE FIRST KFS00730
C EXECUTABLE STATEMENT OF THE SOURCE PROGRAM. KFS00740
C ICOM IS FIXED DECIMAL REPRESENTATION OF ALPHABETIC COMMA. KFS00750
91 NNA=0 KFS00760
101 ICOM=1799372864 KFS00770
    READ (1,2) NPRCBS KFS00780
    DO 1033 KNT=1,NPRCBS KFS00790
    REWIND 10 KFS00800
C READ I.D. KFS00810
    READ(1,2) NC,MNQ,IM KFS00820
    READ(1,86) OW KFS00830
    READ(1,11)(AID(I),I=1,18) KFS00840
C READ CONTROL CARD KFS00850
    READ(1,2) NVIN,NVAR,NCBS,NSEL,FIN,FOUT,IRES,NFC KFS00860
    IF (FIN-FOUT) 101C, 730,730 KFS00870
730 IF(NNA.NE.1) GO TO 740 KFS00880
    READ(1,4) ((NAME(I,J),J=1,2),I=1,NVAR) KFS00890
740 IF(NFC.EQ.0)NFC=1 KFS00900
    NFC=NFC*20 KFS00910
    READ(1,1) (FMT(I),I=1,NFC) KFS00920
C INITIALIZE. KFS00930
    OBS=NOBS KFS00940
    NINDV=NVAR-1 KFS00950
    DO 90 I=1,NVAR KFS00960
    XBAR(I)=0.0 KFS00970
    SIGMA(I)=0.0 KFS00980
    DO 90 J=1,NVAR KFS00990
    RIJ(I,J)=0.0 KFS01000
C READ DATA, FORM SUMS VECTOR, SUMS OF SQUARES MATRIX KFS01010
    READ(1,FMT)(DATX(J),J=1,NOBS) KFS01020
    DO 110 I=1,NOBS KFS01030
    DATA(I)=DATX(I) KFS01040
C TRANSFORMATION OF RAW DATA KFS01050
750 CALL TRANS(DATA,I) KFS01060
860 IF(IRES)870,880,870 KFS01070
C WRITE DATA FILE KFS01080
870 WRITE(10)(DATA(J),J=1,NVAR) KFS01090
880 DO 100 J=1,NVAR KFS01100
    XBAR(J)=XBAR(J)+DATA(J) KFS01110
    DO 100 K=1,NVAR KFS01120
    RIJ(J,K)=RIJ(J,K)+DATA(J)*DATA(K) KFS01130
100 CONTINUE KFS01140
C COMPUTE STANDARD DEVIATIONS*SCR ROUTE (OBS-1) KFS01150
    DO 120 I=1,NVAR KFS01160
120 SIGMA(I)=(RIJ(I,I)-XBAR(I)*XBAR(I)/OBS)**.5 KFS01170
C COMPUTE CORRELATION MATRIX KFS01180

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```

DO 130 I=1,NVAR
DO 130 J=1,NVAR
RIJ(I,J)=(RIJ(I,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 XXBAR(I)=XBAR(I)
C SKIP TO NEW PAGE, WRITE I.O., AVERAGES, STANDARD DEVIATIONS,
C AND SIMPLE CORRELATION MATRIX.
WRITE(3,65)(AID(I),I=1,18)
IF(NNA.NE.1) GO TC 741
WRITE(3,51)
WRITE(3,6)(I,(NAME(I,J),J=1,2),I=1,NVAR)
741 WRITE(3,51)
WRITE(3,52)(I,XBAR(I),(COM,I=1,NINDV),NVAR,XBAR(NVAR))
WRITE(3,53)
WRITE(3,52)(I,SIGMA(I),(COM,I=1,NINDV),NVAR,SIGMA(NVAR))
WRITE(3,55)
DO 150 I=1,NINDV
150 WRITE(3,56)(I,J,RIJ(I,J),ICOM,J=1,NINDV),I,NVAR,RIJ(I,NVAR)
C PHASE 2. PERFORM STEPWISE CALCULATIONS AND PRINT RESULTS.
IF(NSEL)1030,1030,1031
1031 DO 1032 NI=1,NSEL
READ(1,84) NDEP, NIIN, (ISAVE(I),I=1,NIIN)
WRITE(3,69) NI,NDEP,NIIN
DO 151 I=1,NVAR
SIGMA(I)=SSIGMA(I)
XBAR(I)=XXBAR(I)
DO 151 J=1,NVAR
151 RIJ(I,J)=RRIJ(I,J)
C INITIALIZE
DO 190 I=1,NVAR
SIGB(I)=0.0
190 B(I)=0.0
NENT=0
DF=OBS-1.0
NSTEP=-1
C TRANSFORM SIGMA VECTOR FROM STANDARD DEVIATIONS TO SQUARE
C ROOTS OF SUMS OF SQUARES.
DO 310 I=1,NVAR
310 SIGMA(I)=SIGMA(I)*(OBS-1.0)**.5
C BEGIN STEP NUMBER NSTEP.
200 NSTEP=NSTEP+1
STDEE=((RIJ(NDEP,NDEP)/DF)**.5)*SIGMA(NDEP)
DF=DF-1.0
IF (DF) 1000,1000,205
205 VMIN=0.0
VMAX=0.0
NIN=0
NIINI=NIIN+1
ISAVE(NIINI)=NDEP
C FIND MINIMUM VARIANCE CONTRIBUTION OF VARIABLES IN REGRESSION
C EQUATION. FIND MAXIMUM VARIANCE CONTRIBUTION OF VARIABLES
C NOT IN REGRESSION EQUATION.
DO 300 I2=1,NIINI
I=ISAVE(I2)
IF(I.EQ.NDEP) GO TO 300

```

KFS01190
KFS01200
KFS01210
KFS01220
KFS01230
KFS01240
KFS01250
KFS01260
KFS01270
KFS01280
KFS01290
KFS01300
KFS01310
KFS01320
KFS01330
KFS01340
KFS01350
KFS01360
KFS01370
KFS01380
KFS01390
KFS01400
KFS01410
KFS01420
KFS01430
KFS01440
KFS01450
KFS01460
KFS01470
KFS01480
KFS01490
KFS01500
KFS01510
KFS01520
KFS01530
KFS01540
KFS01550
KFS01560
KFS01570
KFS01580
KFS01590
KFS01600
KFS01610
KFS01620
KFS01630
KFS01640
KFS01650
KFS01660
KFS01670
KFS01680
KFS01690
KFS01700
KFS01710
KFS01720
KFS01730
KFS01740
KFS01750
KFS01760
KFS01770
KFS01780


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      IF(RIJ(1,1)-.001)300,300,210
210 VI=RIJ(1,NDEP)*RIJ(NDEP,1)/RIJ(1,1)
      IF(VI)240,300,220
220 IF(VI-VMAX)300,300,230
230 VMAX=VI
      NMAX=I
      GO TO 300
240 NIN=NIN+1
      ID(NIN)=I
C   COMPUTE REGRESSION COEFFICIENT AND ITS STANDARD DEVIATION.
      B(NIN)=RIJ(1,NDEP)*SIGMA(NDEP)/SIGMA(1)
      SIGB(NIN)=(STDEE*RIJ(1,1)**.5)/SIGMA(1)
      IF(VMIN)250,260,1000
250 IF(VI-VMIN)300,300,260
260 VMIN=VI
      NMIN=I
300 CONTINUE
      IF(NIN)1000,460,400
C   COMPUTE CONSTANT TERM.
400 BSUBO=XBAR(NDEP)
      DO 410 I=1,NIN
      J=ID(I)
410 BSUBO=BSUBO-B(I)*XBAR(J)
      IF(NENT)1000,480,421
C   OUTPUT FOR VARIABLE ADDED
421 IF(NNA.NE.1) GO TO 420
      WRITE(3,7) NSTEP,K,(NAME(K,I),I=1,2)
      GO TO 425
420 WRITE(3,57)NSTEP,K
425 WRITE(3,58)STDEE
      R=(1.-RIJ(NDEP,NDEP))**.5
      WRITE(3,59)R
      IDFN=OBS-DF-2.0
      IDFO=DF+1.0
      F=(SIGMA(NDEP)**2-(STDEE**2)*(DF+1.0))/((OBS-DF-2.0)*STDEE**2)
      WRITE(3,66)IDFN,ICFD,F
      WRITE(3,60)BSUBO
      WRITE(3,61)
      WRITE(3,62)
      DO 430 I=1,NIN
      J=ID(I)
      T=B(I)/SIGB(I)
430 WRITE(3,63)ID(I),B(I),SIGB(I),T,RIJ(I,NDEP)
C   COMPUTE F LEVEL FOR MINIMUM VARIANCE CONTRIBUTION VARIABLE
C   IN REGRESSION EQUATION.
      FLEV1=VMIN*OF/RIJ(NDEP,NDEP)
      IF(FOUT+FLEV1)460,460,450
C   INITIALIZE FOR REMOVAL OF VARIABLE K FROM EQUATION.
450 K=NMIN
      NENT=0
      DF=DF+2.0
      GO TO 500
C   COMPUTE F LEVEL FOR MAXIMUM VARIANCE CONTRIBUTION VARIABLE
C   NOT IN EQUATION.
460 FLEV1=VMAX*OF/(RIJ(NDEP,NDEP)-VMAX)
      IF(FLEV1-FINI600,600,470)
C   INITIALIZE FOR ENTRY OF VARIABLE K INTO EQUATION.
470 K=NMAX
      NENT=K
      GO TO 500

```

KFS01790
 KFS01800
 KFS01810
 KFS01820
 KFS01830
 KFS01840
 KFS01850
 KFS01860
 KFS01870
 KFS01880
 KFS01890
 KFS01900
 KFS01910
 KFS01920
 KFS01930
 KFS01940
 KFS01950
 KFS01960
 KFS01970
 KFS01980
 KFS01990
 KFS02000
 KFS02010
 KFS02020
 KFS02030
 KFS02040
 KFS02050
 KFS02060
 KFS02070
 KFS02080
 KFS02090
 KFS02100
 KFS02110
 KFS02120
 KFS02130
 KFS02140
 KFS02150
 KFS02160
 KFS02170
 KFS02180
 KFS02190
 KFS02200
 KFS02210
 KFS02220
 KFS02230
 KFS02240
 KFS02250
 KFS02260
 KFS02270
 KFS02280
 KFS02290
 KFS02300
 KFS02310
 KFS02320
 KFS02330
 KFS02340
 KFS02350
 KFS02360
 KFS02370
 KFS02380

C	OUTPUT FOR VARIABLE DELETED	KFS02390
480	WRITE(3,64)NSTEP,K	KFS02400
	GO TO 425	KFS02410
C	UPDATE MATRIX	KFS02420
500	DO 540 I2=1,NIIIN1	KFS02430
	I=ISAVE(I2)	KFS02440
	IF(I-K)510,540,510	KFS02450
510	DO 530 J2=1,NIIIN1	KFS02460
	J=ISAVE(J2)	KFS02470
	IF(J-K)520,530,520	KFS02480
520	RIJ(I,J)=RIJ(I,J)-RIJ(I,K)*RIJ(K,J)/RIJ(K,K)	KFS02490
530	CONTINUE	KFS02500
540	CONTINUE	KFS02510
	DO 560 J2=1,NIIIN1	KFS02520
	J=ISAVE(J2)	KFS02530
	IF(J-K)550,560,550	KFS02540
550	RIJ(K,J)=RIJ(K,J)/RIJ(K,K)	KFS02550
560	CONTINUE	KFS02560
	DO 580 I2=1,NIIIN1	KFS02570
	I=ISAVE(I2)	KFS02580
	IF(I-K)570,580,570	KFS02590
570	RIJ(I,K)=-RIJ(I,K)/RIJ(K,K)	KFS02600
580	CONTINUE	KFS02610
	RIJ(K,K)=1.0/RIJ(K,K)	KFS02620
	GO TO 200	KFS02630
600	IF(IRES)610,1032,610	KFS02640
C	PRINT RESIDUALS	KFS02650
610	REWIND 10	KFS02660
	DO 630 KO=1,NOBS	KFS02670
	READ(10)(DATA(I),I=1,NVAR)	KFS02680
	EST=BSUBO	KFS02690
	DO 620 I=1,NIN	KFS02700
	J=ID(I)	KFS02710
620	EST=EST+B(I)*DATA(J)	KFS02720
	ZRESO(KO)=DATA(NDEP)-EST	KFS02730
630	CONTINUE	KFS02740
	REWIND 10	KFS02750
	NO=1	KFS02760
	CALL SPLIT(NOBS,ZRESO,NO,DW)	KFS02770
	CALL PARZN1(ZRESO,NOBS,NO,MNQ,IW,DW)	KFS02780
1032	CONTINUE	KFS02790
1033	CONTINUE	KFS02800
	WRITE(3,85)	KFS02810
	GO TO 1020	KFS02820
1000	WRITE(3,82)	KFS02830
	GO TO 1020	KFS02840
1030	WRITE(3,80)	KFS02850
	GO TO 1020	KFS02860
1010	WRITE(3,83)	KFS02870
1020	STOP	KFS02880
	END	KFS02890

```

C
C
C      SUBROUTINE TRANS(CATA,I)
C
C      DIMENSION DATA(30)
C      DOUBLE PRECISION CATA,DSIN,DCOS,PI
C      PI=3.1415927
C      JDX=(I-1)/735
C      FI=1-735*JDX
C      DO 5 J=22,28
C      5 DATA(J)=0.0
C      DO 10 J=7,12
C      10 DATA(J)=0.
C      DATA(2)=FI
C      DATA(3)=DCOS(2.*PI*FI/182.5)
C      DATA(4)=DSIN(2.*PI*FI/182.5)
C      DATA(5)=DCOS(2.*PI*FI/365.)
C      DATA(6)=DSIN(2.*PI*FI/365.)
C      IDX=1/7
C      IDX=1-IDX*7
C
C      DAY 1 IS MONDAY
C
C      IF(IDX .EQ. 1) GO TO 20
C      IF(IDX .EQ. 2) GO TO 30
C      IF(IDX .EQ. 3) GO TO 40
C      IF(IDX .EQ. 4) GO TO 50
C      IF(IDX .EQ. 5) GO TO 60
C      IF(IDX .EQ. 6) GO TO 70
C      GO TO 80
C      20 DATA(7)=1.
C      GO TO 80
C      30 DATA(8)=1.
C      GO TO 80
C      40 DATA(9)=1.
C      GO TO 80
C      50 DATA(10)=1.
C      GO TO 80
C      60 DATA(11)=1.
C      GO TO 80
C      70 DATA(12)=1.
C      80 CONTINUE
C      DATA(13)=FI*FI/10000.
C      DATA(14)=DCOS(2.*PI*FI/91.25)
C      DATA(15)=DSIN(2.*PI*FI/91.25)
C      DATA(16)=DCOS(2.*PI*FI/45.625)
C      DATA(17)=DSIN(2.*PI*FI/45.625)
C      DATA(18)=DCOS(2.*PI*FI/30.416)
C      DATA(19)=DSIN(2.*PI*FI/30.416)
C      DATA(20)=DCOS(2.*PI*FI/60.83)
C      DATA(21)=DSIN(2.*PI*FI/60.83)
C      IF (JDX .EQ. 1) GO TO 90
C      IF (JDX .EQ. 2) GO TO 100
C      IF (JDX .EQ. 3) GO TO 110
C      IF (JDX .EQ. 4) GO TO 120
C      IF (JDX .EQ. 5) GO TO 125
C      IF (JDX .EQ. 6) GO TO 126
C      IF (JDX .EQ. 7) GO TO 127
C      GO TO 130

```

KFS02900

KFS02910

KFS02920

KFS02930

KFS02940

KFS02950

KFS02960

KFS02970

KFS02980

KFS02990

KFS03000

KFS03010

KFS03020

KFS03030

KFS03040

KFS03050

KFS03060

KFS03070

KFS03080

KFS03090

KFS03100

KFS03110

KFS03120

KFS03130

KFS03140

KFS03150

KFS03160

KFS03170

KFS03180

KFS03190

KFS03200

KFS03210

KFS03220

KFS03230

KFS03240

KFS03250

KFS03260

KFS03270

KFS03280

KFS03290

KFS03300

KFS03310

KFS03320

KFS03330

KFS03340

KFS03350

KFS03360

KFS03370

KFS03380

KFS03390

KFS03400

KFS03410

KFS03420

KFS03430

KFS03440

KFS03450

```
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
```

```
KFS03460  
KFS03470  
KFS03480  
KFS03490  
KFS03500  
KFS03510  
KFS03520  
KFS03530  
KFS03540  
KFS03550  
KFS03560  
KFS03570  
KFS03580  
KFS03590  
KFS03600  
KFS03610
```

```

C
C
C      SUBROUTINE PARZN1(X,N,NQ,M,IW,DW)
C
C      THIS PROCEDURE COMPUTES THE AUTO CORRELATION FUNCTION, R1, FOR
C      I=1,2,...,M+1. THE FUNCTION AT LAG M IS STORED AT I=M+1. THE
C      TIME SERIES ARE OF LENGTH, N, AND IS STORED IN THE ARRAY Y,
C      BEGINNING AT L1. THE AUTO CORRELATION FUNCTION IS NORMALIZED
C      TO HAVE A VALUE 1 AT THE ORIGIN. THE NORMALIZING FACTOR IS D1.
C      THE FUNCTIONS ARE ADDED INTO THE ARRAY R1.
C
1  FORMAT(2I4)
2  FORMAT(4X,F5.0,4X,F5.0)
3  FORMAT(F12.5,12X,F12.5)
   DIMENSION X(1)
   REAL R1(750)/750*(C.0/
   DATA D1,D3/0.0,0.0,C/
   MM=0
   DO 5 I=1,N
     D1=D1+X(I)**2
5  CONTINUE
   MM=M+1
   DO 7 KK=1,MM
     KK1=KK-1
     NM=N+KK-1
     NK=N-KK+1
     SUM1=0.0
     DO 6 JL=1,NK
       SUM1=SUM1+X(JL)*X(JL+KK1)
6  CONTINUE
     R1(KK)=SUM1/D1
7  CONTINUE
   CALL SPLOT(M,R1,2,DW)
   CALL PARZN2(R1,NQ,M,IW,DW)
   RETURN
   END

```

KFS02030
 KFS02040
 KFS02050
 KFS02060
 KFS02070
 KFS02080
 KFS02090
 KFS02100
 KFS02110
 KFS02120
 KFS02130
 KFS02140
 KFS02150
 KFS02160
 KFS02170
 KFS02180
 KFS02190
 KFS02200
 KFS02210
 KFS02220
 KFS02230
 KFS02240
 KFS02250
 KFS02260
 KFS02270
 KFS02280
 KFS02290
 KFS02300
 KFS02310
 KFS02320
 KFS02330
 KFS02340
 KFS02350
 KFS02360

```

C
C
C      SUBROUTINE PARZN2(R1,NQ,M,IW,DW)                                KFS02370
C
C      THIS PROCEDURE COMPUTES N+1 POINTS OF THE ESTIMATED SPECTRAL    KFS02380
C      DENSITY FUNCTION FROM R(I) WHICH IS THE AUTO CORRELATION FUNCTION KFS02390
C      THE TRUNCATION POINT IS M, THE WEIGHTING KERNEL USED IS OMEGA.    KFS02400
C      THE SINES AND COSINES NEEDED ARE COMPUTED RECURSIVELY            KFS02410
C                                                                           KFS02420
C                                                                           KFS02430
C                                                                           KFS02440
C      DIMENSION R1(750)                                                KFS02450
C      REAL OMEGA(750)/750*0.0/,F1(750)/750*0.0/                        KFS02460
C      PI=3.1415927                                                       KFS02470
C      PIV=1/PI                                                            KFS02480
C      1 FORMAT(4F10.5)                                                    KFS02490
C      2 FORMAT(' RESULTS OF PARZEN TRANSFORM'//,F1,F2)                  KFS02500
C      1 CO      QU// (F10.5,10X,F10.5))                                  KFS02510
C      IF(IW) 32,30,32                                                    KFS02520
C                                                                           KFS02530
C      PARZEN WINDOW                                                       KFS02540
C      32 M1=M/2                                                            KFS02550
C      M2=M1+1                                                             KFS02560
C      DO 33 I=1,M1                                                         KFS02570
C      33 OMEGA(I)=1.0-6.0*(I*1.0/M)**2+6.0*(I*1.0/M)**3                KFS02580
C      DO 34 I=M2,M                                                         KFS02590
C      34 OMEGA(I)=2*(1-I/M)**3                                             KFS02600
C      GO TO 31                                                            KFS02610
C      TUKEY HANNING WINDOW                                                KFS02620
C      30 DO 3 I=1,M                                                         KFS02630
C      3 OMEGA(I)=.5*(1.0+COS(I*PI/M))                                     KFS02640
C      31 C=NQ                                                                KFS02650
C      C1=COS(DW)                                                            KFS02660
C      C3=C1                                                                KFS02670
C      D1=C1                                                                KFS02680
C      C2=SIN(DW)                                                            KFS02690
C      D4=C2                                                                KFS02700
C      D6=2.0*C1                                                            KFS02710
C      P1=0.5*R1(1)                                                         KFS02720
C      K=M+1                                                                KFS02730
C      DO 4 I=2,K                                                            KFS02740
C      A=OMEGA(I)                                                            KFS02750
C      P1=P1+R1(I)*A                                                         KFS02760
C      4 CONTINUE                                                            KFS02770
C      F1(1)=P1*PIV                                                         KFS02780
C      DO 6 I=1,NQ                                                            KFS02790
C      U11=0.0                                                                KFS02800
C      U12=U11                                                                KFS02810
C      U13=U11                                                                KFS02820
C      U14=U11                                                                KFS02830
C      U21=U11                                                                KFS02840
C      U22=U11                                                                KFS02850
C      DO 5 J=2,K                                                            KFS02860
C      JJ=M+3-J                                                                KFS02870
C      A=OMEGA(JJ)                                                            KFS02880
C      U31=D6*U21-U11+R1(JJ)*A                                              KFS02890
C      U11=U21                                                                KFS02900
C      U21=U31                                                                KFS02910
C      U12=U22                                                                KFS02920
C      5 CONTINUE                                                            KFS02930
C      F1(I+1)=(D1*U21-U11+R1(I)*0.5)*PIV

```

```
D1=(C1*C3)-(C2*D4)
D4=(D4*C1)+(C3*C2)
C3=D1
D6=2.0*D1
6 CONTINUE
CALL SPLOT(NQ,F1,3,DW)
RETURN
END
```

```
KFS02940
KFS02950
KFS02960
KFS02970
KFS02980
KFS02990
KFS03000
KFS03010
```

```

C
C
C      SUBROUTINE SPLOT(N,X,NO,DW)                                KFS03020
C
C      THIS ROUTINE IS USED TO MODIFY THE RESULTS FROM THE PARZEN SUBR KFS03030
C      SO THAT THEY CAN BE GRAPHED BY SUBROUTINE PLOT.           KFS03040
C                                                                KFS03050
C                                                                KFS03060
C      DIMENSION X(800),CUT(101),YPR(11),ANG(9),PLT(1600),Y(800) KFS03070
102  FORMAT(' PLOT VALLES ',1/8F14.5)) KFS03080
C                                                                KFS03090
C      INITIALIZE VALUES KFS03100
C      PI=3.1415927 KFS03110
C      K=0 KFS03120
C      M=2 KFS03130
C      IF(NO.NE.3)      GC TO 10 KFS03140
C      DO 106 I=1,N KFS03150
C      IF(X(I))100,100,95 KFS03160
C      99 X(I)=ALOG(X(I)) KFS03170
C      GO TO 106 KFS03180
100  X(I)=-10.0 KFS03190
106  CONTINUE KFS03200
C      DO 8 I=1,N KFS03210
C      PLT(I)=I*DW KFS03220
C      PLT(I+N)=X(I) KFS03230
C      8 CONTINUE KFS03240
C      GO TO 20 KFS03250
10  DO 11 I=1,N KFS03260
C      PLT(I)=I KFS03270
C      PLT(I+N)=X(I) KFS03280
11  CONTINUE KFS03290
20  CALL PLOT(NO,PLT,N,M,N,0) KFS03300
C      WRITE(3,102) (X(I),I=1,N) KFS03310
C      RETURN KFS03320
C      END KFS03330

```



```

C
C      SUBROUTINE PLOT(NC,A,N,M,NL,NS)
C
C      DIMENSION OUT(101),YPR(11),ANG(9),A(11)
C
C      1 FORMAT(1H1,60X,7H CHART ,I3,/)
C      2 FORMAT(1H ,F11.4,5H+ ,101A1)
C      3 FORMAT(1H )
C      4 FORMAT(10H *+0156789)
C      5 FORMAT( 10A1)
C      7 FORMAT(1H ,16X,101H. . . . .)
C      8 FORMAT(1H0,9X,11F10.4//)
C      9 FORMAT(1H ,16X,101A1)
C      200 FORMAT( 10X,'      PLOT OF DATA')
C      201 FORMAT( 10X,'      PLOT OF AUTO CORR. FUNCTION')
C      202 FORMAT( 10X,'      PLOT OF SPECTRUM')
C
C      .....
C      NLL=NL
C
C      IF(NS)16,16,10
C
C      SORT BASE VARIABLE IN ASCENDING ORDER
C
C      10 DO 15 I=1,N
C         DO 14 J=1,N
C            IF(A(I)-A(J))14,14,11
C      11 L=I-N
C         LL=J-N
C         DO 12 K=L,M
C            L=L+N
C            LL=LL+N
C            F=A(L)
C            A(LL)=A(LL)
C      12 A(LL)=F
C      14 CONTINUE
C      15 CONTINUE
C
C      TEST NLL
C
C      16 IF(NLL)20,18,20
C      18 NLL=50
C
C      PRINT TITLE
C
C      20 WRITE(3,1)NO
C         GO TO (91,92,93),NO
C      91 WRITE(3,200)
C         GO TO 21
C      92 WRITE(3,201)
C         GO TO 21
C      93 WRITE(3,202)
C      21 CONTINUE
C
C      DEVELOP BLANKS AND DIGITS FOR PRINTING

```

KFS03340
 KFS03350
 KFS03360
 KFS03370
 KFS03380
 KFS03390
 KFS03400
 KFS03410
 KFS03420
 KFS03430
 KFS03440
 KFS03450
 KFS03460
 KFS03470
 KFS03480
 KFS03490
 KFS03500
 KFS03510
 KFS03520
 KFS03530
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 KFS03570
 KFS03580
 KFS03590
 KFS03600
 KFS03610
 KFS03620
 KFS03630
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 KFS03670
 KFS03680
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 KFS03700
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 KFS03770
 KFS03780
 KFS03790
 KFS03800
 KFS03810
 KFS03820
 KFS03830
 KFS03840
 KFS03850
 KFS03860
 KFS03870
 KFS03880
 KFS03890
 KFS03900

	REWIND 4	KFS03910
	WRITE(4,4)	KFS03920
	REWIND 4	KFS03930
	READ(4,5)BLANK,(ANG(I),I=1,9)	KFS03940
	REWIND 4	KFS03950
C		KFS03960
C	FIND SCALE FOR BASE VARIABLE	KFS03970
C		KFS03980
	XSCAL=(A(N)-A(1))/(FLOAT(NLL-1))	KFS03990
C		KFS04000
C	FIND SCALE FOR CROSS VARIABLES	KFS04010
C		KFS04020
	M1=N+1	KFS04030
	YMIN=A(M1)	KFS04040
	YMAX=YMIN	KFS04050
	M2=M*N	KFS04060
	DO 40 J=M1,M2	KFS04070
	IF(A(J)-YMIN)28,28,26	KFS04080
26	IF(A(J)-YMAX)40,40,30	KFS04090
28	YMIN=A(J)	KFS04100
	GO TO 40	KFS04110
30	YMAX=A(J)	KFS04120
40	CONTINUE	KFS04130
	YSCAL=(YMAX-YMIN)/100.0	KFS04140
C		KFS04150
C	FIND BASE VARIABLE PRINT POSITION	KFS04160
C		KFS04170
	XB=A(1)	KFS04180
	L=1	KFS04190
	MY=M-1	KFS04200
	I=1	KFS04210
45	F=I-1	KFS04220
	XPR=XB+F*XSCAL	KFS04230
C	IF(A(L)-XPR)51,51,70	KFS04240
C		KFS04250
C	FIND CROSS VARIABLES	KFS04260
C		KFS04270
51	DO 55 IX=1,101	KFS04280
55	OUT(IX)=BLANK	KFS04290
57	DO 60 J=1,MY	KFS04300
	LL=L+J*N	KFS04310
	JP=((A(LL)-YMIN)/YSCAL)+1.0	KFS04320
	OUT(JP)=ANG(J)	KFS04330
60	CONTINUE	KFS04340
C		KFS04350
C	PRINT LINE AND CLEAR, OR SKIP	KFS04360
C		KFS04370
	WRITE(3,2)XPR,(OUT(IZ),IZ=1,101)	KFS04380
	L=L+1	KFS04390
	GO TO 80	KFS04400
70	WRITE(3,3)	KFS04410
80	I=I+1	KFS04420
	IF(I-NLL)45,84,86	KFS04430
84	XPR=A(N)	KFS04440
	GO TO 51	KFS04450
C		KFS04460
C	PRINT CROSS VARIABLES NUMBERS	KFS04470
C		KFS04480
86	WRITE(3,7)	KFS04490
	YPR(L)=YMIN	KFS04500

```
      DO 90 KN=1,9
90  YPR(KN+1)=YPR(KN)+YSCAL*10.0
      YPR(11)=YMAX
      WRITE(3,8)(YPR(IR),IR=1,11)
      RETURN
      END
```

```
KFS04510
KFS04520
KFS04530
KFS04540
KFS04550
KFS04560
```

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 I10.

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 follws 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:

$\text{COF}(1,J)$ - The J^{th} coefficient of the 1^{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.

```

C                                     KFS00000
C THE MAIN PROGRAM READS IN ALL INITIAL VALUES OR PRESETS THEM FOR THE KFS00010
C BEGINNING OF THE SIMULATION, AS WELL AS KEEPS TRACK OF TIME AND THE KFS00020
C CURRENT EVENT. KFS00030
C                                     KFS00040
C      COMMON SMRM(25,18), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(KFS00050
      10), YY(10), COF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREKFS00060
      ZAD, RL, RU, GF, UF, CTUN, CTCD, TUNT, NDEF0, NSFTS, SHTR, SHTP KFS00070
      COMMON/NWK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(KFS00080
      12,25), NPR(25) KFS00090
      DIMENSION P(20) KFS00100
C                                     KFS00110
C      INITIALIZATION KFS00120
C                                     KFS00130
C      NREAD=5 KFS00140
      NWRIT=6 KFS00150
      PI=3.1415927 KFS00160
      DO 5 I=1,25 KFS00170
      NPR(I)=0 KFS00180
      DO 5 J=1,18 KFS00190
      5 SMRM(I,J)=0.0 KFS00200
      DO 10 I=1,25 KFS00210
      DO 10 J=1,25 KFS00220
      TIM(I,J)=0.0 KFS00230
      DIS(I,J)=0.0 KFS00240
      SSAV(I,J)=0.0 KFS00250
      10 CM(I,J)=0.0 KFS00260
      DO 15 I=1,10 KFS00270
      DO 15 J=1,16 KFS00280
      15 VMRM(I,J)=0.0 KFS00290
      TUNT=0.0 KFS00300
      LRT=0 KFS00310
      NDEF0=0 KFS00320
      SHTR=0.0 KFS00330
      SHTP=0.0 KFS00340
C                                     KFS00350
C      READ IN DATA KFS00360
C                                     KFS00370
C      READ(NREAD,1000) NSTAT, NV, NC, NT, NM, NSP, NVP, ITIM, ICH, IRPT, KFS00380
      IIX, NSFTS KFS00390
      1000 FORMAT(10I5,11O,15) KFS00400
      READ(NREAD,1005) CR, CP, CC, CD, CMT, COP, CLT, RL, RU, UF, UF, CT KFS00410
      IUN, CTCD KFS00420
      DO 17 J=1,N7 KFS00430
      XH(J)=0.0 KFS00440
      YH(J)=1.0 KFS00450
      READ(NREAD,1005) P(J) KFS00460
      X(J)=SIN(2.*PI/P(J)) KFS00470
      17 Y(J)=COS(2.*PI/P(J)) KFS00480
      DO 18 I=1,NM KFS00490
      18 READ(NREAD,1005) (COF(I,J),J=1,NC) KFS00500
      1005 FORMAT(8F10.4) KFS00510
      DO 19 I=1,NSTAT KFS00520
      19 READ(NREAD,1006) IT1(I), ST2(I,1), ST2(I,2) KFS00530
      1006 FORMAT(12,2F10.4) KFS00540
      DO 20 I=1,NSTAT KFS00550
      20 READ(NREAD,1020) (SMRM(I,J),J=1,NSP) KFS00560
      1020 FORMAT(10F8.2) KFS00570
      DO 30 I=1,NV KFS00580
      30 READ(NREAD,1020) (VMRM(I,J),J=1,NVP) KFS00590

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```

      IOX=1
      DO 40 I=1,NSTAT
      READ(NREAD,1030)(DIS(I,J),J=1,IOX)
1030 FCRMAT(20F4.1)
      40 IOX=IOX+1
      IOX=1
      DO 50 I=1,NSTAT
      READ(NREAD,1030)(TIM(I,J),J=1,IOX)
      50 IOX=IOX+1
C
C   CALCULATE SAVINGS FOR CLARKE AND WRIGHT PROCEDURE IN TERMS OF THE TOTAL TRANSPORTATION COST
C
      IOX=1
      DO 65 I=1,NSTAT
      DO 60 J=1,IOX
      60 CM(I,J)=CD*TIM(I,J)+(CMT+CDP)*DIS(I,J)
      65 IOX=IOX+1
      JDX=NSTAT-1
      IOX=1
      DO 75 J=1,JDX
      DO 70 I=IOX,JDX
      SSAV(I,J)=CM(J,1)+CM(I+1,1)-CM(I+1,J+1)
      70 CONTINUE
      75 IOX=IOX+1
C
C   ECHO CHECK
C
      IF (ICM.EQ. 0) GO TO 300
      WRITE(NWRIT,1040)
1040 FORMAT(1H1,50X,' ECHO CHECK OF INPUT DATA ',//)
      WRITE(NWRIT,1050) ITIM, NSTAT, NV, NSFTS, NSP, NVP, NM, NC, NT, IX
1050 FORMAT(//,19X,' TOTAL SIMULATED TIME ',I5,' DAYS',/,19X,' NUMBER OF STATIONS',I4,/,19X,' NUMBER OF VEHICLES ',I3,/,19X,' NUMBER OF SHIFTS ',I3,/,19X,' NUMBER OF STATION CHARACTERISTICS INPUT ',I3,/,19X,' NUMBER OF VEHICLE CHARACTERISTICS INPUT ',I3,/,19X,' NUMBER OF MODELS ',I3,/,19X,' NUMBER OF MODEL TERMS ',I3,/,19X,' NUMBER OF TRIG. TERMS ',I3,/,19X,' SEED VALUE ',I10)
      WRITE(NWRIT,1060) CR, CP, CC, CD, CMT, CDP, CLT
1060 FORMAT(//,19X,' COST OF REGULAR GASOLINE AT THE TERMINAL ',F6.3,' PER GALLON',/,19X,' COST OF PREMIUM GASOLINE AT THE TERMINAL ',F6.3,' PER GALLON',/,19X,' INVENTORY CARRYING COST (% PRODUCT COST) ',F6.3,' PER YEAR',/,19X,' DRIVERS WAGES ',F6.3,' PER HOUR',/,19X,' VEHICLE MAINTENANCE COST ',F6.3,' PER MILE',/,19X,' VEHICLE OPERATING COST ',F6.3,' PER MILE',/,19X,' TAXES AND LICENSING ',F8.2,' PER VEHICLE PER YEAR')
      WRITE(NWRIT,1065) CTLD, RL, CTUN, RU, DF, UF
1065 FORMAT(//,19X,' CONSTANT LOADING TIME',F6.2,' HOURS',/,19X,' LOAD IN RATE ',F6.2,' GPM',/,19X,' CONSTANT UNLOADING TIME',F6.2,' HOURS',/,19X,' UNLOADING RATE',F7.2,' GPM',/,19X,' DELIVERY FACTOR',F6.3,/,19X,' MINIMUM LOADING FACTOR ',F6.3)
      WRITE(NWRIT,1070)
1070 FORMAT(//,54X,' MODEL COEFFICIENTS',/)
      WRITE(NWRIT,1075) (J,J=1,NM)
1075 FORMAT(5X,' COEFFICIENT',7X,10(12,8X),/)
      DO 110 J=1,NC
      110 WRITE(NWRIT,1080) J, (COF(I,J),I=1,NM)
1080 FORMAT(10X,12,8X,10F10.4)
      WRITE(NWRIT,1090)
1090 FORMAT(1H1,//,40X,' INITIAL VALUES FOR TRIGONOMETRIC FUNCTIONS',/)

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WRITE(NWRIT,1092) KFS01200
1092 FORMAT(11X,' PERIOD',15X,'SINE',14X,'INITIAL',14X,'COSINE',14X,'INCKFS01210
INITIAL',/,30X,' INCREMENT',10X,'SINE VALUE',11X,'INCREMENT',10X,'COKFS01220
2SINE VALUE',/) KFS01230
CO 120 J=1,NT KFS01240
120 WRITE(NWRIT,1100) P(J), X(J), XH(J), Y(J), YH(J) KFS01250
1100 FORMAT(11X,F8.4,12X,F8.4,12X,F8.4,12X,F8.4,12X,F8.4) KFS01260
WRITE(NWRIT,1110) KFS01270
1110 FORMAT(//,20X,' STATION ',13X,' REGULAR CONSTANT ',13X,'KFS01280
1 PREMIUM CONSTANT ',/,18X,' NUMBER',2X,'TYPE',/) KFS01290
DO 130 J=1,NSTAT KFS01300
130 WRITE(NWRIT,1120) J, IT1(J), ST2(J,1), ST2(J,2) KFS01310
1120 FORMAT(21X,I2,4X,I2,26X,F9.4,24X,F9.4) KFS01320
NSP1=NSP-1 KFS01330
WRITE(NWRIT,1130) (J,J=1,NSP1) KFS01340
1130 FORMAT(1H1,/,39X,' STATION MASTER REFERENCE MATRIX ',/,10X,' NUMBKFS01350
1ER',5X,I2,8(8X,I2),/) KFS01360
CO 140 I=1,NSTAT KFS01370
140 WRITE(NWRIT,1140) (SMRM(I,J),J=1,9) KFS01380
1140 FORMAT(5X,F10.0,2X,BF10.2) KFS01390
WRITE(NWRIT,1150) (J,J=1,8) KFS01400
1150 FORMAT(//,39X,' VEHICLE MASTER REFERENCE MATRIX',/,10X,' NUMBER',5KFS01410
IX,I2,8(8X,I2),/) KFS01420
CO 150 I=1,NV KFS01430
150 WRITE(NWRIT,1140) (VMRM(I,J), J=1,9) KFS01440
WRITE(NWRIT,1160) KFS01450
1160 FORMAT(1H1,/,57X,' DISTANCE MATRIX ') KFS01460
IDX=1 KFS01470
DO 160 I=1,NSTAT KFS01480
WRITE(NWRIT,1170) (DIS(I,J), J=1,IDX) KFS01490
1170 FORMAT(25F5.1) KFS01500
160 IDX=IDX+1 KFS01510
WRITE(NWRIT,1180) KFS01520
1180 FORMAT(//,59X,' TIME MATRIX ') KFS01530
IDX=1 KFS01540
DO 170 I=1,NSTAT KFS01550
WRITE(NWRIT,1190) (TIM(I,J), J=1,IDX) KFS01560
1190 FORMAT(25F5.2) KFS01570
170 IDX=IDX+1 KFS01580
WRITE(NWRIT,1200) KFS01590
1200 FORMAT(1H1,/,59X,' COST MATRIX ') KFS01600
IDX=1 KFS01610
DO 180 I=1,NSTAT KFS01620
WRITE(NWRIT,1190) (CM(I,J),J=1,IDX) KFS01630
180 IDX=IDX+1 KFS01640
WRITE(NWRIT,1210) KFS01650
1210 FORMAT(//,57X,' SAVINGS MATRIX ') KFS01660
IDX=1 KFS01670
INDX=NSTAT-1 KFS01680
DO 190 I=1,INDX KFS01690
WRITE(NWRIT,1190) (SSAV(I,J), J=1,IDX) KFS01700
190 IDX=IDX+1 KFS01710
300 CONTINUE KFS01720
RU=RU*60.0 KFS01730
RL=RL*60.0 KFS01740
RPTP=IRPT KFS01750
RPTP=RPTP/365. KFS01760
CC=CC*RPTP KFS01770
CLT=CLT*RPTP KFS01780
KFS01790

```

C

C EVENT SCHEDULING AND MONITORING

C

```
      I=1
100  IDX=I/IRPT
      IDX=I-IDX*IRPT
      CALL STDAY(I,NC,NT,NM,IX)
      IF (IDX .EQ. 0) GO TO 210
      GO TO 220
210  CALL RPTRT(I,CR,CF,CC,CD,CMT,COP,CLT,LRT,IRPT)
220  IF (I .EQ. ITIM) GO TO 200
      I=I+1
      GO TO 100
200  CONTINUE
      STOP
      END
```

KFS01800
KFS01810
KFS01820
KFS01830
KFS01840
KFS01850
KFS01860
KFS01870
KFS01880
KFS01890
KFS01900
KFS01910
KFS01920
KFS01930
KFS01940

```

SUBROUTINE STOAY(I,NC,NT,NM,IX)
C
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), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(
110), YY(10), CDF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREKFS02030
ZAD, RL, RU, DF, UF, CTUN, CTLD, TUNT, NDEF0, NSFTS, SHTR, SHTP
COMMON/NTWK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(
12,25), NPR(25)
DIMENSION VCM(30), TOT(10), RN(2), WEDM(25,4)
IDX=1/7
IDX=1-IDX*7
PI=3.1415927
IF (IDX .EQ. 0) GO TO 8
C
C RESET VEHICLE DAILY MILEAGE TOTALS, UPDATE INVENTORY RECORDS
C
DO 1 J=1,NV
1 VMRM(J,14)=0.0
DO 2 J=1,NSTAT
IF (NPR(J) .EQ. 4) GO TO 3
NPR(J)=0
3 SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
2 SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
DO 7 J=1,2
DO 7 JX=1,NSTAT
7 OFILE(J,JX)=0.0
GO TO 15
8 DO 9 J=1,NSTAT
SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
SMRM(J,6)=SMRM(J,6)-WEDM(J,1)
SMRM(J,7)=SMRM(J,7)-WEDM(J,2)
SMRM(J,8)=SMRM(J,8)-WEDM(J,3)
IF (SMRM(J,8) .GT. 0.0) GO TO 4
SHTR=SHTR-SMRM(J,8)
SMRM(J,8)=0.0
4 SMRM(J,9)=SMRM(J,9)-WEDM(J,4)
IF (SMRM(J,9) .GT. 0.0) GO TO 9
SHTP=SHTP-SMRM(J,9)
SMRM(J,9)=0.0
9 CONTINUE
GO TO 120
C
C SET UP ITERATIVE SIN - COS ROUTINE
C
15 DO 10 J=1,NT
XX(J)=XH(J)*Y(J)+YH(J)*X(J)
YY(J)=YH(J)*Y(J)-XH(J)*X(J)
XH(J)=XX(J)
10 YH(J)=YY(J)
C
C CREATE MULTIPLIER VECTOR
C
DO 20 J=1,30
20 VCM(J)=0.0
SI=1*I

```

KFS01950
KFS01960
KFS01970
KFS01980
KFS01990
KFS02000
KFS02010
KFS02020
KFS02030
KFS02040
KFS02050
KFS02060
KFS02070
KFS02080
KFS02090
KFS02100
KFS02110
KFS02120
KFS02130
KFS02140
KFS02150
KFS02160
KFS02170
KFS02180
KFS02190
KFS02200
KFS02210
KFS02220
KFS02230
KFS02240
KFS02250
KFS02260
KFS02270
KFS02280
KFS02290
KFS02300
KFS02310
KFS02320
KFS02330
KFS02340
KFS02350
KFS02360
KFS02370
KFS02380
KFS02390
KFS02400
KFS02410
KFS02420
KFS02430
KFS02440
KFS02450
KFS02460
KFS02470
KFS02480
KFS02490
KFS02500
KFS02510
KFS02520
KFS02530
KFS02540

```

VCM(1)=1.0
VCM(2)=1
VCM(3)=51/10000.
JDX=4
DO 30 J=1,N1
VCM(JDX)=X(J)
VCM(JDX+1)=Y(J)
30 JDX=JDX+2
IF (IDX .EQ. 0) GO TO 35
VCM(16+IDX)=1.0
35 CONTINUE
DO 40 J=1,NM
TOT(J)=0.0
40 DO 50 JX=1,NM
DO 50 J=1,22
50 TOT(JX)=TOT(JX)+VCM(J)*CUF(JX,J)
DO 70 J=1,NSTAT
DRF=TOT(11(J))+ST2(J,1)
DPF=TOT(11(J)+NM/2)+ST2(J,2)
C
C GENERATE 'RANDOM' VARIATION
C
DO 55 JX=1,2
IY=IX*65539
IF (IY) 5,6,6
5 IY=IY+2147483647+1
6 YFL=IY
YFL=YFL*.4656613E-9
IX=IY
Z=((1.-YFL)**(-.16239)-1.)*.20517-(YFL**(-.16239)-1.)*.20517/.
13240
55 R1(JX)=Z*COF(JX*11(J),NC)
C
C UPDATE STATUS. CREATE ORDER FILE
C
IF (IDX .EQ. 0) GO TO 65
DRA=DRF+RN(1)
DPA=DPF+RN(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 (DPA .LE. 0.0) DPA=0.0
SMRM(J,6)=SMRM(J,6)-DRF
SMRM(J,7)=SMRM(J,7)-DPF
SMRM(J,8)=SMRM(J,8)-DRA
IF (SMRM(J,8) .GT. 0.0) GO TO 56
SHTR=SHTR-SMRM(J,8)
SMRM(J,8)=0.0
56 SMRM(J,9)=SMRM(J,9)+DPA
IF (SMRM(J,9) .GT. 0.0) GO TO 54
SHTP=SHTP-SMRM(J,9)
SMRM(J,9)=0.0
54 SMRM(J,17)=SMRM(J,17)+DRA
SMRM(J,18)=SMRM(J,18)+DPA
IF (NPR(J) .NE. 4) GO TO 57
SMRM(J,12)=SMRM(J,12)+1.
NPR(J)=2
GO TO 60
57 IF ((SMRM(J,6)-SMRM(J,4)) .LE. 0.0) NPR(J)=1
IF ((SMRM(J,7)-SMRM(J,5)) .LE. 0.0) NPR(J)=1

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KFS02550
KFS02560
KFS02570
KFS02580
KFS02590
KFS02600
KFS02610
KFS02620
KFS02630
KFS02640
KFS02650
KFS02660
KFS02670
KFS02680
KFS02690
KFS02700
KFS02710
KFS02720
KFS02730
KFS02740
KFS02750
KFS02760
KFS02770
KFS02780
KFS02790
KFS02800
KFS02810
KFS02820
KFS02830
KFS02840
KFS02850
KFS02860
KFS02870
KFS02880
KFS02890
KFS02900
KFS02910
KFS02920
KFS02930
KFS02940
KFS02950
KFS02960
KFS02970
KFS02980
KFS02990
KFS03000
KFS03010
KFS03020
KFS03030
KFS03040
KFS03050
KFS03060
KFS03070
KFS03080
KFS03090
KFS03100
KFS03110
KFS03120
KFS03130
KFS03140

IF (NPR(J) .GT. 0) GO TO 60	KFS03150
IF ((SMRM(J,6)-SMRM(J,4)) .LE. 0.0) NPR(J)=2	KFS03160
IF ((SMRM(J,9)-SMRM(J,5)) .LE. 0.0) NPR(J)=2	KFS03170
IF (NPR(J) .EQ. 0) GO TO 70	KFS03180
OFILE(1,J)=SMRM(J,2)-SMRM(J,8)	KFS03190
OFILE(2,J)=SMRM(J,3)-SMRM(J,9)	KFS03200
SMRM(J,12)=SMRM(J,12)+1.	KFS03210
GO TO 70	KFS03220
60 OFILE(1,J)=SMRM(J,2)-(SMRM(J,6)+DRF)	KFS03230
OFILE(2,J)=SMRM(J,3)-(SMRM(J,7)+CPF)	KFS03240
GO TO 70	KFS03250
C C C	KFS03260
DETERMINE SUNDAY DEMAND FOR CREATION OF SATURDAY ORDER FILE.	KFS03270
65 DRA=DRF+RN(1)	KFS03280
DPA=DPF+RN(2)	KFS03290
IF (DRF .LE. 0.0) DRF=0.0	KFS03300
IF (DPF .LE. 0.0) DPF=0.0	KFS03310
IF (DRA .LE. 0.0) DRA=0.0	KFS03320
IF (DPA .LE. 0.0) DPA=0.0	KFS03330
WEDM(J,1)=DRF	KFS03340
WEDM(J,2)=DPF	KFS03350
WEDM(J,3)=DRA	KFS03360
WEDM(J,4)=DPA	KFS03370
SMRM(J,17)=SMRM(J,17)+WEDM(J,3)	KFS03380
SMRM(J,18)=SMRM(J,18)+WEDM(J,4)	KFS03390
70 CONTINUE	KFS03400
IF (IDX .EQ. 0) GO TO 75	KFS03410
IF (IDX .NE. 6) GO TO 110	KFS03420
IDX=0	KFS03430
GO TO 15	KFS03440
75 DO 100 J=1,NSTAT	KFS03450
IF (NPR(J) .NE. 0) GO TO 100	KFS03460
IF ((SMRM(J,6)-WEDM(J,1)-SMRM(J,4)) .LE. 0.0) NPR(J)=1	KFS03470
IF ((SMRM(J,7)-WEDM(J,2)-SMRM(J,5)) .LE. 0.0) NPR(J)=1	KFS03480
IF (NPR(J) .GT. 0) GO TO 90	KFS03490
IF ((SMRM(J,8)-WEDM(J,3)-SMRM(J,4)) .LE. 0.0) NPR(J)=2	KFS03500
IF ((SMRM(J,9)-WEDM(J,4)-SMRM(J,5)) .LE. 0.0) NPR(J)=2	KFS03510
IF (NPR(J) .EQ. 0) GO TO 100	KFS03520
OFILE(1,J)=SMRM(J,2)-SMRM(J,8)	KFS03530
OFILE(2,J)=SMRM(J,3)-SMRM(J,9)	KFS03540
SMRM(J,12)=SMRM(J,12)+1.	KFS03550
GO TO 100	KFS03560
90 OFILE(1,J)=SMRM(J,2)-SMRM(J,6)	KFS03570
OFILE(2,J)=SMRM(J,3)-SMRM(J,7)	
100 CONTINUE	KFS03600
110 CALL ROUT(I)	KFS03610
120 RETURN	KFS03620
END	KFS03630

```

SUBROUTINE ROUT11
COMMON SPRM(25,18), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(KFS03650
110), YY(10), COF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREKFS03660
2AD, RL, RU, DF, UF, CTUN, CTLO, TUNT, NDEF0, NSFTS, SHTR, SHTP KFS03670
COMMON/NTWK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(KFS03680
12,25), NPR(25) KFS03690
DIMENSION SAV(25,25), INIDX(25), IROUT(25,4), TLOAD(2,25), RTTIM(2KFS03700
15), IV(25), XFILE(2,25), RTDIS(25), OVT(10) KFS03710
SFTN=NSFTS KFS03720
DO 2 J=1,2 KFS03730
DO 2 K=1,NSTAT KFS03740
XFILE(J,K)=0.0 KFS03750
2 TLOAD(J,K)=0.0 KFS03760
DO 3 J=1,NSTAT KFS03770
3 RTDIS(J)=2.*DIS(J,1) KFS03780
DO 4 J=1,NV KFS03790
4 OVT(J)=0.0 KFS03800
C KFS03810
C INITIALIZE SAVINGS MATRIX KFS03820
C KFS03830
DO 5 J=1,NSTAT KFS03840
DO 5 K=1,NSTAT KFS03850
5 SAV(J,K)=SSAV(J,K) KFS03860
C KFS03870
C ESTABLISH INDIRECT INDEX KFS03880
C KFS03890
JDX=0 KFS03900
DO 20 K=1,NSTAT KFS03910
IF (NPR(K) .NE. 0) GO TO 10 KFS03920
GO TO 20 KFS03930
10 JDX=JDX+1 KFS03940
INIDX(JDX)=K KFS03950
20 CONTINUE KFS03960
IF (JDX .EQ. 0) GO TO 305 KFS03970
DO 30 J=1,NSTAT KFS03980
DO 30 K=1,4 KFS03990
30 IROUT(J,K)=0 KFS04000
C KFS04010
C THIS SECTION MAKES THE INITIAL ALLOCATION OF VEHICLES TO SINGLE STATKFS04020
C ION ROUTES KFS04030
C KFS04040
K=0 KFS04050
50 K=K+1 KFS04060
DO 40 J=1,JDX KFS04070
JNIDX=INIDX(J) KFS04080
LOAD=0 KFS04090
IF ((OFILE(1,JNIDX) .LE. (UF*VMRM(K,5))) .AND. (OFILE(2,JNIDX) .LE.KFS04100
1. (UF*VMRM(K,6)))) GO TO 40 KFS04110
IROUT(JNIDX,1)=2 KFS04120
IROUT(JNIDX,2)=-9 KFS04130
IROUT(JNIDX,3)=-9 KFS04140
IROUT(JNIDX,4)=JNIDX KFS04150
51 IF (OFILE(1,JNIDX) .GE. VMRM(K,5)) GO TO 70 KFS04160
TLOAD(1,JNIDX)=OFILE(1,JNIDX) KFS04170
XFILE(1,JNIDX)=OFILE(1,JNIDX) KFS04180
OFILE(1,JNIDX)=0.0 KFS04190
IF (OFILE(2,JNIDX) .GE. VMRM(K,6)) GO TO 90 KFS04200
TLOAD(2,JNIDX)=OFILE(2,JNIDX) KFS04210
XFILE(2,JNIDX)=OFILE(2,JNIDX) KFS04220
OFILE(2,JNIDX)=0.0 KFS04230

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IF (NPR(JNIDX) .EQ. 2) GO TO 110
TTLOD=TLOAD(1,JNIDX)+TLOAD(2,JNIDX)
RTTIM(JNIDX)=2.*TIM(JNIDX,1)+TTLOD/RL+TTLOD/RU+CTUN+CTLO
55 IF ((VMRM(K,14)+RTTIM(JNIDX)) .LE. VMRM(K,2)) GO TO 56
K=K+1
IF (K .GT. NV) GO TO 57
GO TO 55
57 NDEF0=NDEF0+1
ROUT(JNIDX,1)=0
ROUT(JNIDX,2)=0
NPR(JNIDX)=4
GO TO 40
56 IV(JNIDX)=K
VMRM(K,9)=VMRM(K,5)+1.
VMRM(K,10)=VMRM(K,10)+RTTIM(JNIDX)
VMRM(K,14)=VMRM(K,14)+RTTIM(JNIDX)
GO TO 40
70 TLOAD(1,JNIDX)=VMRM(K,5)
IF ((OFIL(1,JNIDX)*UF) .GT. VMRM(K,5)) GO TO 80
OFIL(1,JNIDX)=OFIL(1,JNIDX)-VMRM(K,5)
IF (OFIL(2,JNIDX) .GT. VMRM(K,6)) GO TO 90
75 TLOAD(2,JNIDX)=OFIL(2,JNIDX)
77 OFIL(1,JNIDX)=0.
78 OFIL(2,JNIDX)=0.
GO TO 110
90 TLOAD(2,JNIDX)=VMRM(K,6)
IF ((OF*OFIL(2,JNIDX)) .GT. VMRM(K,6)) GO TO 100
GO TO 77
100 OFIL(2,JNIDX)=OFIL(2,JNIDX)-VMRM(K,6)
GO TO 110
80 OFIL(1,JNIDX)=OFIL(1,JNIDX)-VMRM(K,5)
IF (OFIL(2,JNIDX) .GT. VMRM(K,6)) GO TO 85
TLOAD(2,JNIDX)=OFIL(2,JNIDX)
GO TO 78
85 TLOAD(2,JNIDX)=VMRM(K,6)
OFIL(2,JNIDX)=OFIL(2,JNIDX)-TLOAD(2,JNIDX)
110 TTLOD=TLOAD(1,JNIDX)+TLOAD(2,JNIDX)
TTIM=2.*TIM(JNIDX,1)+TTLOD/RL+TTLOD/RU+CTUN+CTLO
RTTIM(JNIDX)=TTIM
111 IF ((VMRM(K,2)-VMRM(K,14)) .LT. TTIM) GO TO 115
VMRM(K,14)=VMRM(K,14)+TTIM
IF (TTIM .LE. VMRM(K,7)) GO TO 109
VMRM(K,8)=VMRM(K,8)+TTIM-VMRM(K,7)
OVT(K)=OVT(K)+TTIM-VMRM(K,7)
109 VMRM(K,9)=VMRM(K,5)+1.
VMRM(K,10)=VMRM(K,10)+RTTIM(JNIDX)
VMRM(K,11)=VMRM(K,11)+TLOAD(1,JNIDX)+TLOAD(2,JNIDX)
GO TO 116
115 K=K+1
IF (K .GT. NV) GO TO 114
GO TO 111
114 NDEF0=NDEF0+1
ROUT(JNIDX,1)=0
ROUT(JNIDX,2)=0
NPR(JNIDX)=4
GO TO 40
116 SMRM(JNIDX,14)=SMRM(JNIDX,14)+1.
ACEPTR=SMRM(JNIDX,2)-SMRM(JNIDX,8)
ACEPTR=SMRM(JNIDX,3)-SMRM(JNIDX,9)
IF (ACEPTR .GE. TLOAD(1,JNIDX)) GO TO 117

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KFS04240
KFS04250
KFS04260
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KFS04360
KFS04370
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KFS04400
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KFS04600
KFS04610
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KFS04680
KFS04690
KFS04700
KFS04710
KFS04720
KFS04730
KFS04740
KFS04750
KFS04760
KFS04770
KFS04780
KFS04790
KFS04800
KFS04810
KFS04820
KFS04830


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VMMR(K,15)=VMMR(K,15)+TLOAD(1,JNIDX)-ACEPTR
TLOAD(1,JNIDX)=ACEPTR
LOAD=1
117 IF (ACEPTR .GE. TLOAD(2,JNIDX)) GO TO 118
VMMR(K,15)=VMMR(K,15)+TLOAD(2,JNIDX)-ACEPTR
LOAD=1
TLOAD(2,JNIDX)=ACEPTR
118 IF (LOAD .NE. 1) GO TO 112
VMMR(K,13)=VMMR(K,13) + 1.
OFILE(1,JNIDX)=0.C
OFILE(2,JNIDX)=0.C
112 SMRM(JNIDX,8)=SMRM(JNIDX,8)+TLOAD(1,JNIDX)
SMRM(JNIDX,9)=SMRM(JNIDX,9)+TLOAD(2,JNIDX)
SMRM(JNIDX,6)=SMRM(JNIDX,8)
SMRM(JNIDX,7)=SMRM(JNIDX,9)
SMRM(JNIDX,13)=1
SMRM(JNIDX,15)=SMRM(JNIDX,15)+TLOAD(1,JNIDX)
SMRM(JNIDX,16)=SMRM(JNIDX,16)+TLOAD(2,JNIDX)
IF (NPR(JNIDX) .EQ. 2) GO TO 113
IF ((OFILE(1,JNIDX) .GT. (UF*VMMR(K,5))) .OR. (OFILE(2,JNIDX) .GT.KFS05030
1. (UF*VMMR(K,6)))) GO TO 11
113 XFILE(1,JNIDX)=0.C
XFILE(2,JNIDX)=0.C
IROUT(JNIDX,1)=0
IROUT(JNIDX,2)=0
40 CONTINUE
C
C
C
C
THIS SECTION CARRIES OUT THE CLARKE AND WRIGHT PROCEDURE FOR ROUTE
IMPROVEMENT
DO 45 J=1,2
DO 45 K=1,NSTAT
45 OFILE(J,K)=XFILE(J,K)
IF (JDX .LE. 1) GO TO 170
119 KDX=2
IDX=JDX-1
SAVMX=0.0
LSAV1=0
LSAV2=0
DO 120 K=1,IDX
KNIDX=INIDX(K)
DO 121 J=KDX,JDX
JNIDX=INIDX(J)
LADJ1=0
LADJ2=0
IF (SAV((JNIDX-1),KNIDX) .LT. SAVMX) GO TO 121
IF ((IROUT(KNIDX,1) .EQ. 0) .OR. (IROUT(JNIDX,1) .EQ. 0)) GO TO 12KFS05100
12 IF (IROUT(JNIDX,4) .EQ. IROUT(KNIDX,4)) GO TO 122
IF (((TLOAD(1,JNIDX)+TLOAD(1,KNIDX))*DF) .GT. VMMR(1,5)) GO TO 12KFS05130
IF (((TLOAD(2,JNIDX)+TLOAD(2,KNIDX))*DF) .GT. VMMR(1,6)) GO TO 12KFS05340
ADJR=-TIM(JNIDX,1)-TIM(KNIDX,1)+TIM(JNIDX,(KNIDX+1))
IF ((TLOAD(1,JNIDX)+TLOAD(1,KNIDX)) .LE. VMMR(1,5)) GO TO 126
ADJL=TLOAD(1,JNIDX)+TLOAD(1,KNIDX)-VMMR(1,5)
ADJR=ADJR-ADJL/RU-ADJL/RL
LADJ1=1
126 IF ((TLOAD(2,JNIDX)+TLOAD(2,KNIDX)) .LE. VMMR(1,6)) GO TO 127
ADJL=TLOAD(2,JNIDX)+TLOAD(2,KNIDX)-VMMR(1,6)
ADJR=ADJR-ADJL/RU-ADJL/RL
LADJ2=1

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127 CONTINUE
   TRTIM=RTTIM(JNIDX)+RTTIM(KNIDX)+ADJR-CTLD
   IF (TRTIM .GT. VMRM(1,3)) GO TO 122
   SAVMX=SAV((JNIDX-1),KNIDX)
   JSAV=JNIDX
   KSAV=KNIDX
   LSAV1=LADJ1
   LSAV2=LADJ2
   TRTIMS=TRTIM
   ADJRS=ADJR
   ADJD=-DIS(JSAV,1)-DIS(KSAV,1)+DIS(JSAV,(KSAV+1))
   RTDIS=RTDIS(JSAV)+RTDIS(KSAV)+ADJD
   GO TO 121
122 SAV((JNIDX-1),KNIDX)=-8.
121 CONTINUE
120 KDX=KDX+1
   IF (LSAV1 .EQ. 0) GO TO 123
   TLOAD(1,JSAV)=.5*VMRM(1,5)
   TLOAD(1,KSAV)=.5*VMRM(1,5)
123 IF (LSAV2 .EQ. 0) GO TO 124
   TLOAD(2,JSAV)=.5*VMRM(1,6)
   TLOAD(2,KSAV)=.5*VMRM(1,6)
124 IF (SAVMX .LE. 0.C) GO TO 170
   SAV((JSAV-1),KSAV)=-9.
   RTNE=RTTIM(KSAV)+ADJRS-CTLD
   IF ((VMRM(IV(JSAV),14)+RTNE) .GT. VMRM(IV(JSAV),2)) GO TO 130
   NVH=IV(JSAV)
   VMRM(IV(KSAV),9)=VMRM(IV(KSAV),9)-1.
   VMRM(IV(KSAV),14)=VMRM(IV(KSAV),14)-RTTIM(KSAV)
   VMRM(IV(JSAV),14)=VMRM(IV(JSAV),14)+RTNE
   VMRM(IV(KSAV),10)=VMRM(IV(KSAV),10)-RTDIS(KSAV)
   VMRM(IV(JSAV),10)=VMRM(IV(JSAV),10)+RTDIS(KSAV)+ADJD
   GO TO 125
170 RTNE=RTTIM(JSAV)+ADJRS-CTLD
   IF ((VMRM(IV(KSAV),14)+RTNE) .GT. VMRM(IV(KSAV),2)) GO TO 140
   NVH=IV(KSAV)
   VMRM(IV(JSAV),9)=VMRM(IV(JSAV),9)-1.
   VMRM(IV(JSAV),14)=VMRM(IV(JSAV),14)-RTTIM(JSAV)
   VMRM(IV(KSAV),14)=VMRM(IV(KSAV),14)+RTNE
   VMRM(IV(JSAV),10)=VMRM(IV(JSAV),10)-RTDIS(JSAV)
   VMRM(IV(KSAV),10)=VMRM(IV(KSAV),10)+RTDIS(JSAV)+ADJD
   GO TO 125
140 CU 160 KX=1,NV
   IF ((VMRM(KX,14)+TRTIMS) .GT. VMRM(KX,2)) GO TO 150
   NVH=KX
   IF (IV(JSAV) .EQ. IV(KSAV)) GO TO 145
   VMRM(IV(KSAV),9)=VMRM(IV(KSAV),9)-1.
   VMRM(IV(KSAV),14)=VMRM(IV(KSAV),14)-RTTIM(KSAV)
   VMRM(IV(KSAV),10)=VMRM(IV(KSAV),10)-RTDIS(KSAV)
145 VMRM(IV(JSAV),9)=VMRM(IV(JSAV),9)-1.
   VMRM(KX,9)=VMRM(KX,9)+1.
   VMRM(IV(JSAV),14)=VMRM(IV(JSAV),14)-RTTIM(JSAV)
   VMRM(KX,14)=VMRM(KX,14)+TRTIMS
   VMRM(IV(JSAV),10)=VMRM(IV(JSAV),10)-RTDIS(JSAV)
   VMRM(KX,10)=VMRM(KX,10)+RTDIS
   GO TO 125
150 IF (K .NE. NV) GO TO 160
   GO TO 165
160 CONTINUE
125 IF (IROUF(KSAV,2) .NE. -9) GO TO 400

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KFS05440
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KFS05970
KFS05980
KFS05990
KFS06000
KFS06010
KFS06020
KFS06030

IF (IROUT(JSAB,3) .NE. -9) GO TO 480	KFS06040
IROUT(KSAB,2)=JSAB	KFS06050
IROUT(JSAB,3)=KSAB	KFS06060
GO TO 500	KFS06070
400 IF (IROUT(JSAB,2) .NE. -9) GO TO 450	KFS06080
IROUT(JSAB,2)=KSAB	KFS06090
IROUT(KSAB,3)=JSAB	KFS06100
GO TO 500	KFS06110
450 JX=JSAB	KFS06120
475 IDUM=IROUT(JX,2)	KFS06130
IROUT(JX,2)=IROUT(JX,3)	KFS06140
IROUT(JX,3)=IDUM	KFS06150
IF (IROUT(JX,3) .EQ. -9) GO TO 490	KFS06160
JX=IROUT(JX,3)	KFS06170
GO TO 475	KFS06180
490 IROUT(JSAB,2)=KSAB	KFS06190
IROUT(KSAB,3)=JSAB	KFS06200
GO TO 500	KFS06210
480 JX=JSAB	KFS06220
485 IDUM=IROUT(JX,3)	KFS06230
IROUT(JX,3)=IROUT(JX,2)	KFS06240
IROUT(JX,2)=IDUM	KFS06250
IF (IROUT(JX,2) .EQ. -9) GO TO 510	KFS06260
JX=IROUT(JX,2)	KFS06270
GO TO 485	KFS06280
510 IROUT(JSAB,3)=KSAB	KFS06290
IROUT(KSAB,2)=JSAB	KFS06300
500 JX=JSAB	KFS06310
520 IF (IROUT(JX,2) .EQ. -9) GO TO 530	KFS06320
JX=IROUT(JX,2)	KFS06330
GO TO 520	KFS06340
530 KX=KSAB	KFS06350
540 IF (IROUT(KX,3) .EQ. -9) GO TO 550	KFS06360
KX=IROUT(KX,3)	KFS06370
GO TO 540	KFS06380
550 TLOAD(1,JX)=TLOAD(1,JSAB)+TLOAD(1,KSAB)	KFS06390
TLOAD(1,KX)=TLOAD(1,JX)	KFS06400
TLOAD(2,JX)=TLOAD(2,JSAB)+TLOAD(2,KSAB)	KFS06410
TLOAD(2,KX)=TLOAD(2,JX)	KFS06420
XFILE(1,KX)=XFILE(1,KSAB)+XFILE(1,JSAB)	KFS06430
XFILE(2,KX)=XFILE(2,KSAB)+XFILE(2,JSAB)	KFS06440
XFILE(1,JX)=XFILE(1,KX)	KFS06450
XFILE(2,JX)=XFILE(2,KX)	KFS06460
IROUT(JSAB,1)=IROUT(JSAB,1)-1	KFS06470
IROUT(KSAB,1)=IROUT(KSAB,1)-1	KFS06480
RTTIM(JX)=RTTIMS	KFS06490
RTTIM(KX)=RTTIMS	KFS06500
RTDIS(JX)=RTDIS	KFS06510
RTDIS(KX)=RTDIS	KFS06520
IV(JX)=NVH	KFS06530
IV(KX)=NVH	KFS06540
IROUT(KSAB,4)=IROUT(KX,4)	KFS06550
IROUT(JSAB,4)=IROUT(KX,4)	KFS06560
IROUT(JX,4)=IROUT(KX,4)	KFS06570
165 IF (SAVMX .GT. 0.0) GO TO 119	KFS06580
C	KFS06590
C STATION STATISTICS UPDATE	KFS06600
C	KFS06610
170 DO 300 J=1,NSTAT	KFS06620
IF (IROUT(J,2) .NE. -9) GO TO 300	KFS06630

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JNDX=J
175 IF (XFILE(1,J) .GT. 1.0) GO TO 176
    FACTR=0.0
    GO TO 177
176 FACTR=TLQAD(1,J)/XFILE(1,J)
177 IF (XFILE(2,J) .GT. 1.0) GO TO 178
    FACTP=0.0
    GO TO 179
178 FACTP=TLQAD(2,J)/XFILE(2,J)
179 CONTINUE
    ACEPTR=SMRM(JNDX,2)-SMRM(JNDX,8)
    IF (ACEPTR .GT. (FACTR*OFILE(1,JNDX))) GO TO 180
    SMRM(JNDX,8)=SMRM(JNDX,8)+ACEPTR
    SMRM(JNDX,6)=SMRM(JNDX,8)
    SMRM(JNDX,15)=SMRM(JNDX,15)+ACEPTR
    VMRM(IV(J),11)=VMRM(IV(J),11)+ACEPTR
    TLQAD(1,J)=TLQAD(1,J)-ACEPTR
    GO TO 190
180 DEVR=FACTR*OFILE(1,JNDX)
    SMRM(JNDX,8)=SMRM(JNDX,8)+DEVR
    SMRM(JNDX,6)=SMRM(JNDX,8)
    SMRM(JNDX,15)=SMRM(JNDX,15)+DEVR
    VMRM(IV(J),11)=VMRM(IV(J),11)+DEVR
    TLQAD(1,J)=TLQAD(1,J)-DEVR
190 ACEPTP=SMRM(JNDX,3)-SMRM(JNDX,9)
    IF (ACEPTP .GT. (FACTP*OFILE(2,JNDX))) GO TO 205
    SMRM(JNDX,9)=SMRM(JNDX,9)+ACEPTP
    SMRM(JNDX,7)=SMRM(JNDX,9)
    SMRM(JNDX,16)=SMRM(JNDX,16)+ACEPTP
    VMRM(IV(J),11)=VMRM(IV(J),11)+ACEPTP
    TLQAD(2,J)=TLQAD(2,J)-ACEPTP
    GO TO 210
205 DEVP=FACTP*OFILE(2,JNDX)
    SMRM(JNDX,9)=SMRM(JNDX,9)+DEVP
    SMRM(JNDX,7)=SMRM(JNDX,9)
    SMRM(JNDX,16)=SMRM(JNDX,16)+DEVP
    VMRM(IV(J),11)=VMRM(IV(J),11)+DEVP
    TLQAD(2,J)=TLQAD(2,J)-DEVP
210 SMRM(JNDX,13)=1
    SMRM(JNDX,14)=SMRM(JNDX,14)+1
    IF (IROUT(JNDX,3) .EQ. -9) GO TO 220
    XFILE(1,J)=XFILE(1,J)-OFILE(1,JNDX)
    XFILE(2,J)=XFILE(2,J)-OFILE(2,JNDX)
    JNDX=IROUT(JNDX,3)
    GO TO 175
220 IF ((TLQAD(1,J) .LT. 5.0) .AND. (TLQAD(2,J) .LT. 5.0)) GO TO 230
    VMRM(IV(J),15)=VMRM(IV(J),15)+TLQAD(1,J)+TLQAD(2,J)
    VMRM(IV(J),13)=VMRM(IV(J),13)+1
230 IF (RTTIM(J) .LE. VMRM(IV(J),7)) GO TO 300
    VMRM(IV(J),8)=VMRM(IV(J),8)+RTTIM(J)-VMRM(IV(J),7)
    OVT(IV(J))=OVT(IV(J))+RTTIM(J)-VMRM(IV(J),7)
300 CONTINUE
305 DO 310 J=1,NV
    IF ((VMRM(J,14)-SFTN*VMRM(J,7)) .GT. OVT(J)) VMRM(J,8)=VMRM(J,8)+VMRM(J,14)-SFTN*VMRM(J,7)-OVT(J)
    VMRM(J,12)=VMRM(J,12)+VMRM(J,14)
    IF (VMRM(J,14) .GT. (VMRM(J,7)*SFTN)) VMRM(J,14)=VMRM(J,7)*SFTN
310 TUNT=TUNT+SFTN*VMRM(J,7)-VMRM(J,14)
320 RETURN
END

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KFS06640
KFS06650
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KFS07220
KFS07230

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SUBROUTINE RPORT(I,CR,CP,CC,CD,CMT,COP,CLT,LRT,IRPT)      KFS07240
C                                                         KFS07250
C THIS SUBROUTINE PROVIDES A PERIODIC PRINTOUT OF STATISTICS KFS07260
C                                                         KFS07270
COMMON SMRM(25,18), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(10),
110, YY(10), COF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRT, NREK KFS07280
2AD, RL, RU, OF, UF, CTU1, CTLD, TUNT, NDEFD, NSFTS, SHTR, SHTP KFS07300
COMMON/NWK/TIM(25,25), DIS(25,25), Ssav(25,25), CM(25,25), OFILE(KFS07310
12,25), NPR(25)
RPTN=I/IRPT KFS07320
NWKS=(I-LRT)/7 KFS07330
WKS=NWKS KFS07340
DYS=I-LRT-NWKS*7 KFS07350
STIM=I KFS07360
SFTN=NSFTS KFS07370
WRITE(NWRIT,850) STIM KFS07380
850 FORMAT(1H1,53X,' SIMULATED TIME ',F5.0,/) KFS07390
WRITE(NWRIT,870) RPTN KFS07400
870 FORMAT(54X,' REPORT PERIOD ',F5.0,/) KFS07410
STIM=I-LRT KFS07420
LRT=I KFS07430
C                                                         KFS07440
C VEHICLE STATISTICS KFS07450
C                                                         KFS07460
WRITE(NWRIT,1000) KFS07470
1000 FORMAT(55X,' VEHICLE STATISTICS',/) KFS07480
TDC=0.0 KFS07490
TMC=0.0 KFS07500
TOC=0.0 KFS07510
TLC=0.0 KFS07520
TFC=0.0 KFS07530
TNT=0.0 KFS07540
TAV=0.0 KFS07550
TAL=0.0 KFS07560
TAT=0.0 KFS07570
TNG=0.0 KFS07580
TNEX=0.0 KFS07590
TUND=0.0 KFS07600
TOVT=0.0 KFS07610
WRITE(NWRIT,940) KFS07620
940 FORMAT(' VEHICLE',3X,'TOTAL',5X,'AVERAGE',4X,'AVERAGE',3X,'AVERAGE', KFS07630
1',2X,' AVERAGE',4X,'NUMBER OF',5X,'VEHICLE',6X,'VEHICLE',6X,'VEHICLE', KFS07640
2LE',4X,'COST OF',4X,'TOTAL',/, ' NUMBER',4X,'NUMBER',3X,'NUMBER OF', KFS07650
3,4X,'TRIP',6X,'TRIP',3X,' GALLONS ',3X,'TRIPS WITH',3X,'OPERATING', KFS07660
4',3X,'MAINTAINENCE',3X,'CRIVER',4X,'TAXES AND',3X,'COST',/,13X,'', KFS07670
5',5X,'TRIPS PER',3X,'LENGTH',5X,'TIME',4X,'DELIVERED',5X,'EXCESS', KFS07680
67X,'COST',10X,'COST',8X,'COST',5X,'LICENSING') KFS07690
WRITE(NWRIT,950) KFS07700
950 FORMAT(11X,'TRIPS',7X,'DAY',25X,'PER TRIP',7X,'LOAD') KFS07710
DO 200 J=1,NV KFS07720
VN=NV KFS07730
AVTR=VMRM(J,9)/STIM KFS07740
IF (VMRM(J,9) .GT. 0.0) GO TO 955 KFS07750
ATL=0.0 KFS07760
ATT=0.0 KFS07770
AGT=0.0 KFS07780
GO TO 956 KFS07790
955 ATL=VMRM(J,10)/VMRM(J,9) KFS07800
ATT=VMRM(J,12)/VMRM(J,9) KFS07810
AGT=VMRM(J,11)/VMRM(J,9) KFS07820
KFS07830

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956 VCC=VMMR(J,10)*CDF
VDC=(WKS*SFTN*6.*VMMR(J,7)+DYS*SFTN*VMMR(J,7)+VMMR(J,8)*1.5)*CD
VMC=VMMR(J,10)*CMT
VTC=CLT+VDC+VDC+VMC
TOVT=TOVT+VMMR(J,8)
TOC=TOC+VDC
TDC=TDC+VDC
TMC=TMC+VMC
TLC=TLC+CLT
TFC=TFC+VTC
TNT=TNT+VMMR(J,9)
TAL=TAL+VMMR(J,10)
TAT=TAT+VMMR(J,12)
TNG=TNG+VMMR(J,11)
TNEX=TNEX+VMMR(J,13)
TUND=TUND+VMMR(J,15)
WRITE(INWRIT,960) J, VMMR(J,9), AVTR, ATL, ATT, AGT, VMMR(J,13), VOKF508000
IC, VMC, VDC, CLT, VTC
960 FORMAT(3X,I2,5X,F5.0,6X,F6.1,5X,F6.1,4X,F6.1,4X,F8.1,9X,F3.0,4X,F9KFS08020
1.2,4X,F9.2,3X,F9.2,2X,F9.2,1X,F9.2) KFS08030
C C C STATISTICS RESET KFS08040
VMMR(J,8)=0.0 KFS08050
VMMR(J,9)=0.0 KFS08060
VMMR(J,10)=0.0 KFS08070
VMMR(J,11)=0.0 KFS08080
VMMR(J,12)=0.0 KFS08090
VMMR(J,13)=0.0 KFS08100
VMMR(J,15)=0.0 KFS08110
200 CONTINUE KFS08120
IF (TNT .GT. 0.0) GO TO 201 KFS08130
TAG=0.0 KFS08160
GO TO 202 KFS08170
201 TAL=TAL/TNT KFS08180
TAT=TAT/TNT KFS08190
TAG=TNG/TNT KFS08200
TAV=TNT/STIM KFS08210
IF (TNG .GT. 0.0) GO TO 210 KFS08220
AVTC=0.0 KFS08230
GO TO 215 KFS08240
210 AVTC=TFC/TNG KFS08250
215 CRT=CR+AVTC KFS08260
CPT=CP+AVTC KFS08270
WRITE(INWRIT,970) TNT, TAV, TAL, TAT, TAG, TNEX, TOC, TMC, TDC, TLCKF508280
1, TFC KFS08290
970 FORMAT(' TOTAL',3X,F6.0,6X,F6.1,5X,F6.1,4X,F6.1,4X,F8.1,9X,F3.0,4XKFS08300
1,F9.2,4X,F9.2,3X,F9.2,2X,F9.2,1X,F9.2) KFS08310
WRITE(INWRIT,980) TOVT,TUNT,TUND,AVTC KFS08320
980 FORMAT('/', ' TOTAL OVERTIME',12X,F8.1, ' HOURS',/, ' TOTAL IDLE TIME' KFS08330
1,11X,F8.1, ' HOURS',/, ' TOTAL GALLONS EXCESS LOAD ',F8.1, ' GALLONS' KFS08340
2,/, ' AVERAGE TRANSPORTATION COST',3X,F8.5, ' PER GALLON DELIVERED' KFS08350
C C C STATION STATISTICS KFS08360
WRITE(INWRIT,900) KFS08370
900 FORMAT(1H1,54X, ' STATION STATISTICS ',///) KFS08380
TIC=0.0 KFS08390
TNO=0.0 KFS08400
TAOSR=0.0 KFS08410
KFS08420
KFS08430

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      TAOSP=0.0
      TAIR=0.0
      TAIP=0.0
      TXP=0.0
      TADM=0.0
      TADMP=0.0
      WRITE(NWRIT,910)
910  FORMAT(' STATION',8X,'TOTAL',12X,'AVERAGE',14X,'AVERAGE',15X,'AVERKFS08440
      AGE',12X,'STATION',7X,'NUMBER',/, 'NUMBER',9X,'NUMBER',12X,'DAILY'KFS08450
      2,16X,'ORDER',15X,'INVENTORY',10X,'INVENTORY',5X,'EXPEDITED',/,18X,KFS08460
      3'OF',13X,'DEMAND',16X,'SIZE',18X,'LEVEL',13X,'CARRYING',6X,'ORDERS'KFS08470
      4',/,14X,'DELIVERIES',5X,'REGULAR PREMIUM',4X,'REGULAR PREMIUM',6X,KFS08480
      5X,'REGULAR PREMIUM',8X,'COST') KFS08490
      UD 100 J=1,NSTAT KFS08500
      IF (SMRM(J,14) .GT. 0.0) GO TO 220 KFS08510
      AUSR=0.0 KFS08520
      AOSP=0.0 KFS08530
      GO TO 225 KFS08540
220  AOSR=SMRM(J,15)/SMRM(J,14) KFS08550
      AOSP=SMRM(J,16)/SMRM(J,14) KFS08560
225  AIR=SMRM(J,10)/STIM KFS08570
      AIP=SMRM(J,11)/STIM KFS08580
      TADM=TAADM+SMRM(J,17) KFS08590
      TADMP=TAADMP+SMRM(J,18) KFS08600
      TSOLD=TADM+TADMP KFS08610
      SMRM(J,17)=SMRM(J,17)/STIM KFS08620
      SMRM(J,18)=SMRM(J,18)/STIM KFS08630
      STIC=(AIR*CRT+AIP*CPT)*CC KFS08640
      TIC=TIC+STIC KFS08650
      TNO=TNO+SMRM(J,14) KFS08660
      TAOSR=TAOSR+SMRM(J,15) KFS08670
      TAOSP=TAOSP+SMRM(J,16) KFS08680
      TAIR=TAIR+SMRM(J,10) KFS08690
      TAIP=TAIP+SMRM(J,11) KFS08700
      TXP=TXP+SMRM(J,12) KFS08710
      WRITE(NWRIT,920) J, SMRM(J,14), SMRM(J,17), SMRM(J,18), AUSR, AOSP,KFS08720
      1,AIR, AIP, STIC, SMRM(J,12) KFS08730
920  FORMAT(2X,13,12X,F4.0,8X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,4X,F9.1,2X,KFS08740
      19.1,5X,F9.2,7X,F4.0) KFS08750
C
C  STATISTICS RESET KFS08760
C
      TUNT=0.0 KFS08770
      SMRM(J,10)=0.0 KFS08780
      SMRM(J,11)=0.0 KFS08790
      SMRM(J,12)=0.0 KFS08800
      SMRM(J,14)=0.0 KFS08810
      SMRM(J,15)=0.0 KFS08820
      SMRM(J,16)=0.0 KFS08830
      SMRM(J,17)=0.0 KFS08840
      SMRM(J,18)=0.0 KFS08850
100  CONTINUE KFS08860
      STAT=NSTAT KFS08870
      IF (TNO .GT. 0.0) GO TO 230 KFS08880
      TAOSR=0.0 KFS08890
      TAOSP=0.0 KFS08900
      GO TO 235 KFS08910
230  TAOSR=TAOSR/TNO KFS08920
      TAOSP=TAOSP/TNO KFS08930
235  TAIR=TAIR/STIM KFS08940

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TAIP=TAIP/STIM
TADMR=TADMR/STIM
TADMP=TADMP/STIM
WRITE(NWRIT,930) TNO, TADMR, TADMP, TADSR, TAUSP, TAIR, TAIP, TIC,
1TXP
930 FORMAT(' TOTAL',10X,F4.0,8X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,4X,F9.1,
12X,F9.1,5X,F9.2,7X,F4.0)
TAVCST=(TFC+TIC)/TSOLD
WRITE(NWRIT,935) TAVCST, NDEFO, SHTR, SHTP
935 FORMAT(/, ' AVERAGE TOTAL COST',F8.5, ' PER GALLON SOLD',/, ' NUMBER
1 OF DEFERRED ORDERS',15,/, ' LOST SALES REGULAR',F8.1, ' GALLONS',/,
2 ' LOST SALES PREMIUM',F8.1, ' GALLONS')
NDEFO=0
SHTR=0.0
SHTP=0.0
RETURN
END

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NON-COMPARTMENTALIZED VEHICLES PROGRAM

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C                                     KFS00000
C THE MAIN PROGRAM READS IN ALL INITIAL VALUES OR PRESETS THEM FOR THE KFS00010
C BEGINNING OF THE SIMULATION, AS WELL AS KEEPS TRACK OF TIME AND THE KFS00020
C CURRENT EVENT. KFS00030
C                                     KFS00040
C      COMMON SMRM(25,19), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(KFS00050
      I(10), YY(10), COF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREKFS00060
      2AD, RL, RU, UF, UF, CTUN, CTLD, TUNT, NDEFQ, NSFTS, SHTR, SHTP KFS00070
      COMMON/NTWK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), UFILE(KFS00080
      12,25), NPR(2,25) KFS00090
      DIMENSION P(20) KFS00100
C                                     KFS00110
C      INITIALIZATION KFS00120
C                                     KFS00130
C      NREAD=5 KFS00140
      NWRIT=6 KFS00150
      PI=3.1415927 KFS00160
      DO 4 I=1,2 KFS00170
      DO 4 J=1,25 KFS00180
4     NPR(I,J)=0 KFS00190
      DO 5 I=1,25 KFS00200
      DO 5 J=1,19 KFS00210
5     SMRM(I,J)=0.0 KFS00220
      DO 10 I=1,25 KFS00230
      DO 10 J=1,25 KFS00240
      TIM(I,J)=0.0 KFS00250
      DIS(I,J)=0.0 KFS00260
      SSAV(I,J)=0.0 KFS00270
10    CM(I,J)=0.0 KFS00280
      DO 15 I=1,10 KFS00290
      DO 15 J=1,16 KFS00300
15    VMRM(I,J)=0.0 KFS00310
      TUNT=0.0 KFS00320
      NDEFQ=0 KFS00330
      SHTR=0.0 KFS00340
      SHTP=0.0 KFS00350
      LRT=0 KFS00360
C                                     KFS00370
C      READ IN DATA KFS00380
C                                     KFS00390
C      READ(NREAD,1000) NSTAT, NV, NC, NT, NM, NSP, NVP, ITIM, ICH, IRPT, KFS00400
      IIX, NSFTS KFS00410
1000  FORMAT(10I5,1I0,1E) KFS00420
      READ(NREAD,1005) CR, CP, CC, CD, CMT, COP, CLT, RL, RU, DF, UF, CT KFS00430
      IUN, CTLD KFS00440
      DO 17 J=1,NT KFS00450
      XH(J)=0.0 KFS00460
      YH(J)=1.0 KFS00470
      READ(NREAD,1005) F(J) KFS00480
      X(J)=SIN(2.*PI/P(J)) KFS00490
      Y(J)=COS(2.*PI/P(J)) KFS00500
17    DO 18 I=1,NM KFS00510
      READ(NREAD,1005) (COF(I,J),J=1,NC) KFS00520
18    FORMAT(8F10.4) KFS00530
      DO 19 I=1,NSTAT KFS00540
      READ(NREAD,1006) IT1(I), ST2(I,1), ST2(I,2) KFS00550
19    FORMAT(12,2F10.4) KFS00560
      DO 20 I=1,NSTAT KFS00570
      READ(NREAD,1020) (SMRM(I,J),J=1,NSP) KFS00580
20    FORMAT(10F8.2) KFS00590

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DO 30 I=1,NV
30 READ(NREAD,1020)(VMRM(I,J),J=1,NVP)
   IDX=1
   DO 40 I=1,NSTAT
   READ(NREAD,1030)(CIS(I,J),J=1,IDX)
1030 FORMAT(20F4.1)
   40 IDX=IDX+1
   10X=1
   DO 50 I=1,NSTAT
   READ(NREAD,1030)(TIM(I,J),J=1,IDX)
   50 10X=10X+1
   KFS00600
   KFS00610
   KFS00620
   KFS00630
   KFS00640
   KFS00650
   KFS00660
   KFS00670
   KFS00680
   KFS00690
   KFS00700
   KFS00710
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   KFS00790
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   KFS00990
   KFS01000
   KFS01010
   KFS01020
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   KFS01160
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   KFS01190
   KFS01200
   KFS01210
   KFS01220
   KFS01230
   KFS01240
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   KFS01270
   KFS01280
   KFS01290
   KFS01300
   KFS01310
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   KFS01390
   KFS01400
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   KFS02000
   KFS02010
   KFS02020
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   KFS04970
  
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WRITE(NWRIT,1090) KFS01200
1090 FORMAT(1H1,/,40X,' INITIAL VALUES FOR TRIGONOMETRIC FUNCTIONS',/1KFS01210
WRITE(NWRIT,1092) KFS01220
1092 FORMAT(11X,' PERIOD',15X,' SINE',14X,' INITIAL',14X,' COSINE',14X,' INKFS01230
INITIAL',/,30X,' INCREMENT',10X,' SINE VALUE',11X,' INCREMENT',10X,' COKFS01240
2SINE VALUE',/) KFS01250
DO 120 J=1,NT KFS01260
120 WRITE(NWRIT,1100) P(J), X(J), XH(J), Y(J), YH(J) KFS01270
1100 FORMAT(11X,F8.4,12X,F8.4,12X,F8.4,12X,F8.4,12X,F8.4) KFS01280
WRITE(NWRIT,1110) KFS01290
1110 FORMAT(//,20X,' STATION ',13X,' REGULAR CONSTANT ',13X,'KFS01300
1 PREMIUM CONSTANT ',/,18X,' NUMBER',2X,'TYPE',/) KFS01310
DO 130 J=1,NSTAT KFS01320
130 WRITE(NWRIT,1120) J, IT1(J), ST2(J,1), ST2(J,2) KFS01330
1120 FORMAT(21X,I2,4X,I2,26X,F9.4,24X,F9.4) KFS01340
NSP1=NSP-1 KFS01350
WRITE(NWRIT,1130) (J,J=1,NSP1) KFS01360
1130 FORMAT(1H1,/,39X,' STATION MASTER REFERENCE MATRIX ',/,10X,' NUMBKFS01370
IER',5X,I2,8(6X,I2),/) KFS01380
DO 140 I=1,NSTAT KFS01390
140 WRITE(NWRIT,1140) (SMRM(I,J),J=1,9) KFS01400
1140 FORMAT(5X,F10.0,2X,8F10.2) KFS01410
WRITE(NWRIT,1150) (J,J=1,8) KFS01420
1150 FORMAT(//,39X,' VEHICLE MASTER REFERENCE MATRIX',/,10X,' NUMBER',5KFS01430
IX,I2,8(8X,I2),/) KFS01440
DO 150 I=1,NV KFS01450
150 WRITE(NWRIT,1140) (VMRM(I,J), J=1,9) KFS01460
WRITE(NWRIT,1160) KFS01470
1160 FORMAT(1H1,/,57X,' DISTANCE MATRIX ') KFS01480
IDX=1 KFS01490
DO 160 I=1,NSTAT KFS01500
WRITE(NWRIT,1170) (DIS(I,J), J=1,IDX) KFS01510
1170 FORMAT(25F5.1) KFS01520
160 IDX=IDX+1 KFS01530
WRITE(NWRIT,1180) KFS01540
1180 FORMAT(//,59X,' TIME MATRIX ') KFS01550
IDX=1 KFS01560
DO 170 I=1,NSTAT KFS01570
WRITE(NWRIT,1190) (TIM(I,J), J=1,IDX) KFS01580
1190 FORMAT(25F5.2) KFS01590
170 IDX=IDX+1 KFS01600
WRITE(NWRIT,1200) KFS01610
1200 FORMAT(1H1,/,59X,' COST MATRIX ') KFS01620
IDX=1 KFS01630
DO 180 I=1,NSTAT KFS01640
WRITE(NWRIT,1190) (CM(I,J),J=1,IDX) KFS01650
180 IDX=IDX+1 KFS01660
WRITE(NWRIT,1210) KFS01670
1210 FORMAT(//,57X,' SAVINGS MATRIX ') KFS01680
IDX=1 KFS01690
INDX=NSTAT-1 KFS01700
DO 190 I=1,INDX KFS01710
WRITE(NWRIT,1190) (SSAV(I,J), J=1,IDX) KFS01720
190 IDX=IDX+1 KFS01730
300 CONTINUE KFS01740
RU=RU*60.0 KFS01750
RL=RL*60.0 KFS01760
RPTP=IRPT KFS01770
RPTP=RPTP/365. KFS01780
CC=CC*RPTP KFS01790

```

```

      CLT=CLT*RPTP
C
C  EVENT SCHEDULING AND MONITORING
C
      I=1
100  IDX=I/IRPT
      IDX=I-IDX*IRPT
      CALL STDAY(I,NC,NT,NM,IX)
      IF (IDX.EQ. 0) GO TO 210
      GO TO 220
210  CALL RPORT(I,CR,CF,CC,CD,CMT,COP,CLT,LRT,IRPT)
220  IF (I.EQ. IIM) GO TO 200
      I=I+1
      GO TO 100
200  CONTINUE
      STOP
      END

```

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KFS01800
KFS01810
KFS01820
KFS01830
KFS01840
KFS01850
KFS01860
KFS01870
KFS01880
KFS01890
KFS01900
KFS01910
KFS01920
KFS01930
KFS01940
KFS01950
KFS01960

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      SUBROUTINE STDAY(I,NC,NT,NM,IX)
C
C THIS SUBROUTINE MAKES THE DAILY FORECASTS AND UPDATES THE PREDICTED
C AND ACTUAL INVENTORY STATUS FOR EACH STATION. THE PREDICTED AND ACTUAL
C AL STATUS ARE CHECKED AGAINST SAFETY LEVELS TO DETERMINE THE DAY'S
C DELIVERY FILE.
C
      COMMON SMRM(25,19), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(
110), YY(10), COF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREK
2AD, RL, RU, DF, UF, CTUN, CTLO, TUNT, NDEFD, NSFTS, SHTR, SHTP
COMMON/NTWK/TIP(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(
12,25), NPR(2,25)
      DIMENSION VCM(30), TUT(10), RN(2), WEDM(25,4)
      IDX=I/7
      IDX=1-IDX*7
      PI=3.1415927
      IF (IDX .EQ. 0) GO TO 8
C
C RESET VEHICLE DAILY MILEAGE TOTALS, UPDATE INVENTORY RECORDS
C
      DO 1 J=1,NV
1  VMRM(J,14)=0.0
      DO 2 J=1,NSTAT
      SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
2  SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
      DO 3 J=1,2
      DO 3 K=1,NSTAT
      IF (NPR(J,K) .EQ. 4) GO TO 3
      NPR(J,K)=0
3  CONTINUE
      DO 7 J=1,2
      DO 7 JX=1,NSTAT
7  OFILE(J,JX)=0.0
      GO TO 15
8  DO 9 J=1,NSTAT
      SMRM(J,10)=SMRM(J,10)+SMRM(J,8)
      SMRM(J,11)=SMRM(J,11)+SMRM(J,9)
      SMRM(J,6)=SMRM(J,6)-WEDM(J,1)
      SMRM(J,7)=SMRM(J,7)-WEDM(J,2)
      SMRM(J,8)=SMRM(J,8)-WEDM(J,3)
      IF (SMRM(J,6) .GT. 0.0) GO TO 4
      SHTR=SHTR-SMRM(J,6)
      SMRM(J,8)=0.0
4  SMRM(J,9)=SMRM(J,9)-WEDM(J,4)
      IF (SMRM(J,9) .GT. 0.0) GO TO 9
      SHTP=SHTP-SMRM(J,9)
      SMRM(J,9)=0.0
9  CONTINUE
      GO TO 120
C
C SET UP ITERATIVE SIN - COS ROUTINE
C
15 DO 10 J=1,NT
      XX(J)=XH(J)*Y(J)+YH(J)*X(J)
      YY(J)=YH(J)*Y(J)-XH(J)*X(J)
      XH(J)=XX(J)
10 YH(J)=YY(J)
C
C CREATE MULTIPLIER VECTOR
C

```

```

DO 20 J=1,30
20 VCM(J)=0.0
SI=I*I
VCM(1)=1.0
VCM(2)=I
VCM(3)=SI/10000.
JDX=4
DO 30 J=1,NT
VCM(JDX)=X(J)
VCM(JDX+1)=Y(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
DO 50 JX=1,NM
DO 50 J=1,22
50 TOT(JX)=TOT(JX)+VCM(J)*COF(JX,J)
DO 70 J=1,NSTAT
DRF=TOT(IT1(J))+ST2(J,1)
DPF=TOT(IT1(J)+NM/2)+ST2(J,2)
C
C GENERATE 'RANDOM' VARIATION
C
DO 55 JX=1,2
IY=IX*65539
IF (IY) 5,6,6
5 IY=IY+2147483647+1
6 YFL=IY
YFL=YFL*.4656613E-9
IX=IY
Z=((1.-YFL)**(-.16239)-1.)*.20517-(YFL**(-.16239)-1.)*.20517/.
13240
55 RN(JX)=Z*COF(JX*IT1(J),NC)
C
C UPDATE STATUS. CREATE ORDER FILE
C
IF (IDX .EQ. 0) GO TO 65
DRA=DRF+RN(1)
DPA=DPF+RN(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 (DPA .LE. 0.0) DPA=0.0
SMRM(J,6)=SMRM(J,6)-DRF
SMRM(J,7)=SMRM(J,7)-DPF
SMRM(J,8)=SMRM(J,8)-DRA
IF (SMRM(J,8) .GT. 0.0) GO TO 56
SHTR=SHTR-SMRM(J,8)
SMRM(J,8)=0.0
56 SMRM(J,9)=SMRM(J,9)-DPA
IF (SMRM(J,9) .GT. 0.0) GO TO 54
SHTP=SHTP-SMRM(J,9)
SMRM(J,9)=0.0
54 SMRM(J,17)=SMRM(J,17)+DRA
SMRM(J,18)=SMRM(J,18)+DPA
IF (NPR(1,J) .NE. 4) GO TO 60
SMRM(J,12)=SMRM(J,12)+1.
NPR(1,J)=2

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KFS02570
KFS02580
KFS02590
KFS02600
KFS02610
KFS02620
KFS02630
KFS02640
KFS02650
KFS02660
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KFS02680
KFS02690
KFS02700
KFS02710
KFS02720
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KFS02780
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KFS02800
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KFS02890
KFS02900
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KFS02960
KFS02970
KFS02980
KFS02990
KFS03000
KFS03010
KFS03020
KFS03030
KFS03040
KFS03050
KFS03060
KFS03070
KFS03080
KFS03090
KFS03100
KFS03110
KFS03120
KFS03130
KFS03140
KFS03150
KFS03160

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        GO TO 61
60 IF ((SMRM(J,6)-SMRM(J,4)) .GT. 0.0) GO TO 57
    NPR(1,J)=1
61 OFILE(1,J)=SMRM(J,2)-(SMRM(J,6)+DRF)
    GO TO 58
57 IF ((SMRM(J,8)-SMRM(J,4)) .GT. 0.0) GO TO 58
    NPR(1,J)=2
    OFILE(1,J)=SMRM(J,2)-SMRM(J,8)
    SMRM(J,12)=SMRM(J,12)+1.
58 IF (NPR(2,J) .NE. 4) GO TO 53
    SMRM(J,13)=SMRM(J,13)+1.
    NPR(2,J)=2
    GO TO 52
53 IF ((SMRM(J,7)-SMRM(J,5)) .GT. 0.0) GO TO 59
    NPR(2,J)=1
52 OFILE(2,J)=SMRM(J,3)-(SMRM(J,7)+DPF)
    GO TO 70
59 IF ((SMRM(J,9)-SMRM(J,5)) .GT. 0.0) GO TO 70
    NPR(2,J)=2
    OFILE(2,J)=SMRM(J,3)-SMRM(J,9)
    SMRM(J,13)=SMRM(J,13)+1.
    GO TO 70
C
C   DETERMINE SUNDAY DEMAND FOR CREATION OF SATURDAY ORDER FILE.
C
65 DRA=DRF+RN(1)
    CPA=DPF+RN(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 (CPA .LE. 0.0) CPA=0.0
    WECM(J,1)=DRF
    WECM(J,2)=CPA
    WECM(J,3)=DRA
    WECM(J,4)=CPA
    SMRM(J,17)=SMRM(J,17)+WECM(J,3)
    SMRM(J,18)=SMRM(J,18)+WECM(J,4)
70 CONTINUE
    IF (IDX .EQ. 0) GO TO 75
    IF (IDX .NE. 6) GO TO 110
    ICX=0
    GO TO 15
75 CC 100 J=1,NSTAT
    IF (NPR(1,J) .NE. 0) GO TO 85
80 IF ((SMRM(J,6)-WECM(J,1)-SMRM(J,4)) .GT. 0.0) GO TO 82
    NPR(1,J)=1
    OFILE(1,J)=SMRM(J,2)-SMRM(J,6)
    GO TO 85
82 IF ((SMRM(J,8)-WECM(J,3)-SMRM(J,4)) .GT. 0.0) GO TO 85
    NPR(1,J)=2
    OFILE(1,J)=SMRM(J,2)-SMRM(J,8)
    SMRM(J,12)=SMRM(J,12)+1.
85 IF (NPR(2,J) .NE. 0) GO TO 100
    IF ((SMRM(J,7)-WECM(J,2)-SMRM(J,5)) .GT. 0.0) GO TO 87
    NPR(2,J)=1
    OFILE(2,J)=SMRM(J,3)-SMRM(J,7)
    GO TO 100
87 IF ((SMRM(J,9)-WECM(J,4)-SMRM(J,5)) .GT. 0.0) GO TO 100
    NPR(2,J)=2
    OFILE(2,J)=SMRM(J,3)-SMRM(J,9)

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KFS03170
 KFS03180
 KFS03190
 KFS03200
 KFS03210
 KFS03220
 KFS03230
 KFS03240
 KFS03250
 KFS03260
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 KFS03280
 KFS03290
 KFS03300
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 KFS03690
 KFS03700
 KFS03710
 KFS03730
 KFS03740
 KFS03750
 KFS03760


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      SMRM(J,13)=SMRM(J,13)+1.  
100 CONTINUE  
110 CALL ROUT(I)  
120 RETURN  
    END
```

```
KFS03770  
KFS03780  
KFS03790  
KFS03800  
KFS03810
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SUBROUTINE ROUT(I)
COMMON SMRM(25,19), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(KFS03820
110), YY(10), CQF(10,25), ITL(25), ST2(25,2), NSTAT, NV, NWRIT, NREKFS03830
2AD, RL, RU, UF, UF, CTUN, CTLD, TUNT, NDEFD, NSFTS, SHTR, SHTP KFS03850
COMMON/NTRK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(KFS03860
12,25), NPR(2,25) KFS03870
DIMENSION SAV(25,25), INIDX(25), IROUT(25,4), TLOAD(25), RTTIM(25)KFS03880
1, IV(25), XFILE(25), RTDIS(25), OVT(10) KFS03890
SFTN=NSFTS KFS03900
ISW=1 KFS03910
1 DO 2 K=1,NSTAT KFS03920
XFILE(K)=0.0 KFS03930
2 TLOAD(K)=0.0 KFS03940
DO 3 J=1,NSTAT KFS03950
3 RTDIS(J)=2.*DIS(J,1) KFS03960
DO 4 J=1,NV KFS03970
4 OVT(J)=0.0 KFS03980
KFS03990
C INITIALIZE SAVINGS MATRIX KFS04000
C KFS04010
DO 5 J=1,NSTAT KFS04020
DO 5 K=1,NSTAT KFS04030
5 SAV(J,K)=SSAV(J,K) KFS04040
KFS04050
C ESTABLISH INDIRECT INDEX KFS04060
C KFS04070
INDC=ISW-1 KFS04080
JDX=0 KFS04090
DO 20 K=1,NSTAT KFS04100
IF (NPR(ISW,K) .GT. 0) GO TO 10 KFS04110
GO TO 20 KFS04120
10 JDX=JDX+1 KFS04130
INIDX(JDX)=K KFS04140
20 CONTINUE KFS04150
28 IF (JDX .EQ. 0) GO TO 305 KFS04160
DO 30 J=1,NSTAT KFS04170
DO 30 K=1,4 KFS04180
30 IROUT(J,K)=0 KFS04190
KFS04200
C THIS SECTION MAKES THE INITIAL ALLOCATION OF VEHICLES TO SINGLE STAT KFS04210
C ION ROUTES KFS04220
C KFS04230
K=1 KFS04240
DO 40 J=1,JDX KFS04250
JNIDX=INIDX(J) KFS04260
IF (OFILE(ISW,JNIDX) .LE. (UF*VMRM(K,5))) GO TO 40 KFS04270
IROUT(JNIDX,1)=2 KFS04280
IROUT(JNIDX,2)=-9 KFS04290
IROUT(JNIDX,3)=-9 KFS04300
IROUT(JNIDX,4)=JNIDX KFS04310
51 IF (OFILE(ISW,JNIDX) .GE. VMRM(K,5)) GO TO 70 KFS04320
TLOAD(J,JDX) =OFILE(ISW,JNIDX) KFS04330
XFILE(JNIDX)=OFILE(ISW,JNIDX) KFS04340
OFILE(ISW,JNIDX)=0.0 KFS04350
IF (NPR(ISW,JNIDX) .EQ. 2) GO TO 110 KFS04360
TTLD=TLUAD(JNIDX) KFS04370
RTTIM(JNIDX)=2.*TIM(JNIDX,1)+TTLD/RL+TTLD/RU+CTUN+CTLD KFS04380
55 IF ((VMRM(K,14)+*RTTIM(JNIDX)) .LE. VMRM(K,2)) GO TO 56 KFS04390
K=K+1 KFS04400
IF (K .GT. NV) GO TO 57 KFS04410

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GO TO 55
57 NOEFO=NOEFO+1
  IROUT(JNIDX,1)=0
  IROUT(JNIDX,2)=0
  NPR(ISW,JNIDX)=4
  GO TO 40
56 IV(JNIDX)=K
  VMRM(K,9)=VMRM(K,5)+1.
  VMRM(K,10)=VMRM(K,10)+RTDIS(JNIDX)
  VMRM(K,14)=VMRM(K,14)+RTTIM(JNIDX)
  GO TO 40
70 TLOAD(JNIDX)=VMRM(K,5)
  IF ((OFILF(ISW,JNIDX)+DF) .GT. VMRM(K,5)) GO TO 80
  OFILF(ISW,JNIDX)=C.O
  GO TO 110
80 OFILF(ISW,JNIDX)=CFILF(ISW,JNIDX)-VMRM(K,5)
110 TTLOD=TLOAD(JNIDX)
  TTIM=2.*TIM(JNIDX,1)+TTLOD/RL+TTLOD/RU+CTUN+CTLO
  RTTIM(JNIDX)=TTIM
111 IF ((VMRM(K,2)-VMRM(K,14)) .LT. TTIM) GO TO 115
  VMRM(K,14)=VMRM(K,14)+TTIM
  IF (TTIM .LE. VMRM(K,7)) GO TO 109
  VMRM(K,8)=VMRM(K,8)+TTIM-VMRM(K,7)
  OVT(K)=OVT(K)+TTIM-VMRM(K,7)
109 VMRM(K,9)=VMRM(K,5)+1.
  VMRM(K,10)=VMRM(K,10)+RTDIS(JNIDX)
  VMRM(K,11)=VMRM(K,11)+TLOAD(JNIDX)
  GO TO 116
115 K=K+1
  IF (K .GT. NV) GO TO 114
  GO TO 111
114 NOEFO=NOEFO+1
  IROUT(JNIDX,1)=0
  IROUT(JNIDX,2)=0
  NPR(ISW,JNIDX)=4
  GO TO 40
116 SMRM(JNIDX,(14+INEC*5))=SMRM(JNIDX,(14+INDC*5))+1
  ACCEPT=SMRM(JNIDX,(1+ISW))-SMRM(JNIDX,(7+ISW))
  IF (ACCEPT .GE. TLCAD(JNIDX)) GO TO 112
  VMRM(K,15)=VMRM(K,15)+TLOAD(JNIDX)-ACCEPT
  TLOAD(JNIDX)=ACCEPT
  VMRM(K,13)=VMRM(K,13) + 1.
  OFILF(ISW,JNIDX)=C.O
112 SMRM(JNIDX,(7+ISW))=SMRM(JNIDX,(7+ISW))+TLOAD(JNIDX)
  SMRM(JNIDX,(5+ISW))=SMRM(JNIDX,(7+ISW))
  SMRM(JNIDX,(14+ISW))=SMRM(JNIDX,(14+ISW))+TLOAD(JNIDX)
  IF (NPR(ISW,JNIDX) .EQ. 2) GO TO 113
  IF (OFILF(ISW,JNIDX) .GT. (CF*VMRM(K,5))) GO TO 51
113 XFILE(JNIDX)=O.O
  IROUT(JNIDX,1)=0
  IROUT(JNIDX,2)=0
40 CONTINUE

C
C THIS SECTION CARRIES OUT THE CLARKE AND WRIGHT PROCEDURE FOR ROUTE
C IMPROVEMENT
C
DO 45 K=1,NSTAT
45 OFILF(ISW,K)=XFILE(K)
  IF (JDX .LE. 1) GO TO 170
119 KDX=2

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KFS04420
KFS04430
KFS04440
KFS04450
KFS04460
KFS04470
KFS04480
KFS04490
KFS04500
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KFS04580
KFS04590
KFS04600
KFS04610
KFS04620
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KFS04700
KFS04710
KFS04720
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KFS04740
KFS04750
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KFS04930
KFS04940
KFS04950
KFS04960
KFS04970
KFS04980
KFS04990
KFS05000
KFS05010

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      IDX=JDX-1
      SAVMX=0.0
      LSAV1=0
      DO 120 K=1,IDX
      KNIDX=INIDX(K)
      DO 121 J=KDX,JDX
      JNIDX=INIDX(J)
      LADJ1=0
      IF (SAV((JNIDX-1),KNIDX) .LT. SAVMX) GO TO 121
      IF ((IROUT(KNIDX,1) .EQ. 0) .OR. (IROUT(JNIDX,1) .EQ. 0)) GO TO 12
      IF (IROUT(JNIDX,4) .EQ. IROUT(KNIDX,4)) GO TO 122
      IF (((TLOAD(JNIDX)+TLOAD(KNIDX))*DF) .GT. VMRM(1,5)) GO TO 122
      ADJR=-TIM(JNIDX,1)-TIM(KNIDX,1)+TIM(JNIDX,(KNIDX+1))
      IF ((TLOAD(JNIDX)+TLOAD(KNIDX)) .LE. VMRM(1,5)) GO TO 127
      ADJL=TLOAD(JNIDX)+TLOAD(KNIDX) - VMRM(1,5)
      ADJR=ADJR-ADJL/RU-ADJL/RL
      LADJ1=L
127 CONTINUE
      TRTIM=RTTIM(JNIDX)+RTTIM(KNIDX)+ADJR-CTLD
      IF (TRTIM .GT. VMRM(1,3)) GO TO 122
      SAVMX=SAV((JNIDX-1),KNIDX)
      JSAV=JNIDX
      KSAV=KNIDX
      LSAV1=LADJ1
      TRTIMS=TRTIM
      ADJRS=ADJR
      ADJD=-DIS(JSAV,1)-DIS(KSAV,1)+DIS(JSAV,(KSAV+1))
      RTDIS=RTDIS(JSAV)+RTDIS(KSAV)+ADJD
      GO TO 121
122 SAV((JNIDX-1),KNIDX)=~B.
121 CONTINUE
120 KDX=KDX+1
      IF (LSAV1 .EQ. 0) GO TO 124
      TLOAD(JSAV)=.5*VMRM(1,5)
      TLOAD(KSAV)=.5*VMRM(1,5)
124 IF (SAVMX .LE. 0.0) GO TO 170
      SAV((JSAV-1),KSAV)=-9.
      RTNE=RTTIM(KSAV)+ADJRS-CTLD
      IF ((VMRM(IV(JSAV),14)+RTNE) .GT. VMRM(IV(JSAV),2)) GO TO 130
      NVH=IV(JSAV)
      VMRM(IV(KSAV),9)=VMRM(IV(KSAV),9)-1.
      VMRM(IV(KSAV),14)=VMRM(IV(KSAV),14)-RTTIM(KSAV)
      VMRM(IV(JSAV),14)=VMRM(IV(JSAV),14)+RTNE
      VMRM(IV(KSAV),10)=VMRM(IV(KSAV),10)-RTDIS(KSAV)
      VMRM(IV(JSAV),10)=VMRM(IV(JSAV),10)+RTDIS(KSAV)+ADJD
      GO TO 125
130 RTNE=RTTIM(JSAV)+ADJRS-CTLD
      IF ((VMRM(IV(KSAV),14)+RTNE) .GT. VMRM(IV(KSAV),2)) GO TO 140
      NVH=IV(KSAV)
      VMRM(IV(JSAV),9)=VMRM(IV(JSAV),9)-1.
      VMRM(IV(JSAV),14)=VMRM(IV(JSAV),14)-RTTIM(JSAV)
      VMRM(IV(KSAV),14)=VMRM(IV(KSAV),14)+RTNE
      VMRM(IV(JSAV),10)=VMRM(IV(JSAV),10)-RTDIS(JSAV)
      VMRM(IV(KSAV),10)=VMRM(IV(KSAV),10)+RTDIS(JSAV)+ADJD
      GO TO 125
140 DO 160 KX=1,NV
      IF ((VMRM(KX,14)+TRTIMS) .GT. VMRM(KX,2)) GO TO 150
      NVH=KX
      IF (IV(JSAV) .EQ. IV(KSAV)) GO TO 145

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KFS05020
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 KFS05410
 KFS05420
 KFS05430
 KFS05440
 KFS05450
 KFS05460
 KFS05470
 KFS05480
 KFS05490
 KFS05500
 KFS05510
 KFS05520
 KFS05530
 KFS05540
 KFS05550
 KFS05560
 KFS05570
 KFS05580
 KFS05590
 KFS05600
 KFS05610

```

VMMR(IV(KSAV),9)=VMMR(IV(KSAV),9)-1.
VMMR(IV(KSAV),14)=VMMR(IV(KSAV),14)-RTTIM(KSAV)
VMMR(IV(KSAV),10)=VMMR(IV(KSAV),10)-RTDIS(KSAV)
145 VMMR(IV(JSAV),9)=VMMR(IV(JSAV),9)-1.
VMMR(KX,9)=VMMR(KX,9)+1.
VMMR(IV(JSAV),14)=VMMR(IV(JSAV),14)-RTTIM(JSAV)
VMMR(KX,14)=VMMR(KX,14)+TRTIMS
VMMR(IV(JSAV),10)=VMMR(IV(JSAV),10)-RTDIS(JSAV)
VMMR(KX,10)=VMMR(KX,10)+RTDIS
GO TO 125
150 IF (K .NE. NV) GO TO 160
GO TO 165
160 CONTINUE
125 IF (IROUT(KSAV,2) .NE. -9) GO TO 400
IF (IROUT(JSAV,3) .NE. -9) GO TO 480
IROUT(KSAV,2)=JSAV
IROUT(JSAV,3)=KSAV
GO TO 500
400 IF (IROUT(JSAV,2) .NE. -9) GO TO 450
IROUT(JSAV,2)=KSAV
IROUT(KSAV,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(JSAV,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(JSAV,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(JX)=TLOAD(JSAV)+TLOAD(KSAV)
TLOAD(KX)=TLOAD(JX)
XFILE(KX)=XFILE(KSAV)+XFILE(JSAV)
XFILE(JX)=XFILE(KX)
IROUT(JSAV,1)=IROUT(JSAV,1)-1
IROUT(KSAV,1)=IROUT(KSAV,1)-1
RTTIM(JX)=TRTIMS
RTTIM(KX)=TRTIMS
RTDIS(JX)=RTDIS
RTDIS(KX)=RTDIS
IV(JX)=NVH

```

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KFS05620
KFS05630
KFS05640
KFS05650
KFS05660
KFS05670
KFS05680
KFS05690
KFS05700
KFS05710
KFS05720
KFS05730
KFS05740
KFS05750
KFS05760
KFS05770
KFS05780
KFS05790
KFS05800
KFS05810
KFS05820
KFS05830
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KFS05860
KFS05870
KFS05880
KFS05890
KFS05900
KFS05910
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KFS05970
KFS05980
KFS05990
KFS06000
KFS06010
KFS06020
KFS06030
KFS06040
KFS06050
KFS06060
KFS06070
KFS06080
KFS06090
KFS06100
KFS06110
KFS06120
KFS06130
KFS06140
KFS06150
KFS06160
KFS06170
KFS06180
KFS06190
KFS06200
KFS06210

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```

IV(KX)=NVH
IROUT(KSAV,4)=IROUT(KX,4)
IROUT(JSAB,4)=IROUT(KX,4)
IROUT(JX,4)=IROUT(KX,4)
165 IF (SAVMX .GT. 0.0) GO TO 119
C
C   STATION STATISTICS UPDATE
C
170 GO 300 J=1,NSTAT
IF (IROUT(J,2) .NE. -9) GO TO 300
JNDX=J
175 IF (XFILE(J) .GT. 0.0) GO TO 176
FACTR=0.0
GO TO 177
176 FACTR=TLOAD(J)/XFILE(J)
177 ACCEPT=SMRM(JNDX,(1+ISW))-SMRM(JNDX,(7+ISW))
IF (ACCEPT .GT. (FACTR*OFILE(ISW,JNDX))) GO TO 180
SMRM(JNDX,(7+ISW))=SMRM(JNDX,(7+ISW))+ACCEPT
SMRM(JNDX,(5+ISW))=SMRM(JNDX,(7+ISW))
SMRM(JNDX,(14+ISW))=SMRM(JNDX,(14+ISW))+ACCEPT
VMRM(IV(J),11)=VMRM(IV(J),11)+ACCEPT
TLOAD(J)=TLOAD(J)-ACCEPT
GO TO 210
180 DEVR=FACTR*OFILE(ISW,JNDX)
SMRM(JNDX,(7+ISW))=SMRM(JNDX,(7+ISW))+DEVR
SMRM(JNDX,(5+ISW))=SMRM(JNDX,(7+ISW))
SMRM(JNDX,(14+ISW))=SMRM(JNDX,(14+ISW))+DEVR
VMRM(IV(J),11)=VMRM(IV(J),11)+DEVR
TLOAD(J)=TLOAD(J)-DEVR
210 SMRM(JNDX,(14+INDC*5))=SMRM(JNDX,(14+INDC*5))+1.
IF (IROUT(JNDX,3) .EQ. -9) GO TO 220
XFILE(J)=XFILE(J)-OFILE(ISW,JNDX)
JNDX=IROUT(JNDX,3)
GO TO 175
220 IF (TLCAD(J) .LT. 5.0) GO TO 230
VMRM(IV(J),15)=VMRM(IV(J),15)+TLCAD(J)
VMRM(IV(J),13)=VMRM(IV(J),13)+1.
230 IF (RTTIM(J) .LE. VMRM(IV(J),7)) GO TO 300
OVT(IV(J))=OVT(IV(J))+RTTIM(J)-VMRM(IV(J),7)
VMRM(IV(J),8)=VMRM(IV(J),8)+RTTIM(J)-VMRM(IV(J),7)
300 CONTINUE
305 ISW=ISW+1
IF (ISW .EQ. 2) GO TO 1
DO 310 J=1,NV
IF ((VMRM(J,14)-SFTN*VMRM(J,7)) .GT. OVT(J)) VMRM(J,8)=VMRM(J,8)+VMRM(J,14)-SFTN*VMRM(J,7)-OVT(J)
VMRM(J,12)=VMRM(J,12)+VMRM(J,14)
IF (VMRM(J,14) .GT. (VMRM(J,7)*SFTN)) VMRM(J,14)=VMRM(J,7)*SFTN
310 TUNT=SFTN*VMRM(J,7)-VMRM(J,14)
320 RETURN
END

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KFS06220
KFS06230
KFS06240
KFS06250
KFS06270
KFS06280
KFS06290
KFS06300
KFS06310
KFS06320
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KFS06340
KFS06350
KFS06360
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KFS06650
KFS06660
KFS06670
KFS06680
KFS06690
KFS06700
KFS06710
KFS06720
KFS06730

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      SUBROUTINE RPORT(I,CR,CP,CC,CD,CMT,COP,CLT,LRT,IRPT)
C
C   THIS SUBROUTINE PROVIDES A PERIODIC PRINTOUT OF STATISTICS
C
      COMMON SMRM(25,19), VMRM(10,16), X(10), XH(10), XX(10), Y(10), YH(
110), YY(10), CDF(10,25), IT1(25), ST2(25,2), NSTAT, NV, NWRIT, NREK
2AD, RL, RU, DF, UF, CTUV, CTLD, TUNT, NDEFO, NSFTS, SHTR, SHTP
COMMON/NTWK/TIM(25,25), DIS(25,25), SSAV(25,25), CM(25,25), OFILE(
12,25), NPR(2,25)
      RPTN=I/IRPT
      NWKS=(I-LRT)/7
      WKS=NWKS
      DYS=I-LRT-NWKS*7
      STIM=I
      SFTN=NSFTS
      WRITE(NWRIT,850) STIM
850  FORMAT(1H1,53X,' SIMULATED TIME ',F5.0,/)
      WRITE(NWRIT,870) RPTN
870  FORMAT(54X,' REPORT PERIOD ',F5.0,/)
      STIM=I-LRT
      LRT=I
C
C   VEHICLE STATISTICS
C
      WRITE(NWRIT,1000)
1000 FORMAT(55X,' VEHICLE STATISTICS',/)
      TDC=0.0
      TMC=0.0
      TOC=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
      TOVT=0.0
      WRITE(NWRIT,940)
940  FORMAT(' VEHICLE',3X,'TOTAL',5X,'AVERAGE',4X,'AVERAGE',3X,'AVERAGE'
1',2X,' AVERAGE',4X,'NUMBER OF',5X,'VEHICLE',6X,'VEHICLE',6X,'VEHICLE'
2LE',4X,'COST OF',4X,'TOTAL',/,,' NUMBER',4X,'NUMBER',3X,'NUMBER OF'
3,4X,'TRIP',6X,'TRIP',3X,' GALLONS ',3X,'TRIPS WITH',3X,'OPERATING'
4',3X,'MAINTAINENCE',3X,'DRIVER',4X,'TAXES AND',3X,'COST',/,13X,'OF'
5',5X,'TRIPS PER',2X,'LENGTH',5X,'TIME',4X,'DELIVERED',5X,'EXCESS',
67X,'COST',10X,'COST',8X,'COST',5X,'LICENSING')
      WRITE(NWRIT,950)
950  FORMAT(11X,'TRIPS',7X,'DAY',25X,'PER TRIP',7X,'LOAD')
      DO 200 J=1,NV
      VN=NV
      AVTR=VMRM(J,9)/STIM
      IF (VMRM(J,9) .GT. 0.0) GO TO 955
      ATL=0.0
      ATT=0.0
      AGT=0.0
      GO TO 956
955  ATL=VMRM(J,10)/VMRM(J,9)
      ATT=VMRM(J,12)/VMRM(J,9)
      AGT=VMRM(J,11)/VMRM(J,9)

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956 VDC=VMRM(J,10)*COF
VDC=(WKS*SFTN*6.*VMRM(J,7)+DYS*SFTN*VMRM(J,7)+VMRM(J,8)*1.5)*CD
VMC=VMRM(J,10)*CMT
VTC=CLT+VUC+VDC+VMC
TOVT=TOVT+VMRM(J,8)
TOC=TOC+VUC
TDC=TDC+VDC
TMC=TMC+VMC
TLC=TLC+CLT
TFC=TFC+VTC
TNT=TNT+VMRM(J,9)
TAL=TAL+VMRM(J,10)
TAT=TAT+VMRM(J,12)
TNG=TNG+VMRM(J,11)
TNEX=TNEX+VMRM(J,13)
TUND=TUND+VMRM(J,15)
WRITE(NWRIT,960) J, VMRM(J,9), AVTR, ATL, ATT, AGT, VMRM(J,13), VUC
1C, VMC, VDC, CLT, VTC
960 FORMAT(3X,12,5X,F6.0,6X,F6.1,5X,F6.1,4X,F6.1,4X,F8.1,9X,F3.0,4X,F9.2,
1.2,4X,F9.2,3X,F9.2,2X,F9.2,1X,F9.2)
C
C STATISTICS RESET
C
VMRM(J,8)=0.0
VMRM(J,9)=0.0
VMRM(J,10)=0.0
VMRM(J,11)=0.0
VMRM(J,12)=0.0
VMRM(J,13)=0.0
VMRM(J,15)=0.0
200 CONTINUE
IF (TNT .GT. 0.0) GO TO 201
TAG=0.0
GO TO 202
201 TAL=TAL/TNT
TAT=TAT/TNT
TAG=TNG/TNT
202 TAV=TNT/STIM
IF (TNG .GT. 0.0) GO TO 210
AVTC=0.0
GO TO 215
210 AVTC=TFL/TNG
215 CRT=CR+AVTC
CPT=CP+AVTC
WRITE(NWRIT,970) TNT, TAV, TAL, TAT, TAG, TNEX, TOC, TMC, TOC, TLCK
1, TFC
970 FORMAT(' TOTAL',3X,F6.0,6X,F6.1,5X,F6.1,4X,F6.1,4X,F8.1,9X,F3.0,4X,F9.2,
1,F9.2,4X,F9.2,3X,F9.2,2X,F9.2,1X,F9.2)
WRITE(NWRIT,980) TOVT,TUNT,TUND,AVTC
980 FORMAT(' TOTAL OVERTIME',12X,F8.1,' HOURS',/, ' TOTAL IDLE TIME',
1,11X,F8.1,' HOURS',/, ' TOTAL GALLONS EXCESS LOAD ',F8.1,' GALLONS',
2,/, ' AVERAGE TRANSPORTATION COST',3X,F8.5,' PER GALLON DELIVERED')
C
C STATION STATISTICS
C
WRITE(NWRIT,900)
900 FORMAT(1H1,54X,' STATION STATISTICS ',///)
TIC=0.0
TNOP=0.0
TNOR=0.0

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KFS07340
KFS07350
KFS07360
KFS07370
KFS07380
KFS07390
KFS07400
KFS07410
KFS07420
KFS07430
KFS07440
KFS07450
KFS07460
KFS07470
KFS07480
KFS07490
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KFS07610
KFS07620
KFS07630
KFS07640
KFS07650
KFS07660
KFS07670
KFS07680
KFS07690
KFS07700
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KFS07790
KFS07800
KFS07810
KFS07820
KFS07830
KFS07840
KFS07850
KFS07860
KFS07870
KFS07880
KFS07890
KFS07900
KFS07910
KFS07920
KFS07930


```

TAOSR=0.0
TAOSP=0.0
TAIR=0.0
TAIP=0.0
TXPP=0.0
TXPR=0.0
TADMR=0.0
TADMP=0.0
WRITE(NWRIT,910)
910 FORMAT(' STATION',8X,'TOTAL',12X,'AVERAGE',14X,'AVERAGE',15X,'AVERKFS07940
AGE',12X,'STATION',7X,'NUMBER',/, ' NUMBER',9X,'NUMBER',12X,'DAILY'KFS07950
2,16X,'ORDER',15X,'INVENTORY',10X,'INVENTORY',5X,'EXPEDITED',/,18X,KFS07960
3'OF',13X,'DEMAND',16X,'SIZE',18X,'LEVEL',13X,'CARRYING',6X,'ORDERSKFS07970
4',/,14X,'DELIVERIES',73X,'CUST',/,14X,'REG. PREM.',5X,'REGULAR PRKFS07980
5EMIUM',4X,'REGULAR PREMIUM',6X,'REGULAR PREMIUM',18X,'REG. PRKFS07990
6EM.') KFS08000
DO 100 J=1,NSTAT KFS08010
IF (SMRM(J,14) .GT. 0.0) GO TO 220 KFS08020
AOSR=0.0 KFS08030
GO TO 221 KFS08040
220 AOSR=SMRM(J,15)/SMRM(J,14) KFS08050
221 IF (SMRM(J,19) .GT. 0.0) GO TO 222 KFS08060
AOSP=0.0 KFS08070
GO TO 225 KFS08080
222 AOSP=SMRM(J,16)/SMRM(J,19) KFS08090
225 AIR=SMRM(J,10)/STIM KFS08100
AIP=SMRM(J,11)/STIM KFS08110
TADMR=TADMR+SMRM(J,17) KFS08120
TADMP=TADMP+SMRM(J,18) KFS08130
TSOLD=TADMR+TADMP KFS08140
SMRM(J,17)=SMRM(J,17)/STIM KFS08150
SMRM(J,18)=SMRM(J,18)/STIM KFS08160
STIC=(AIR*CRT+AIP*CPT)*CC KFS08170
TIC=TIC+STIC KFS08180
TNOR=TNOR+SMRM(J,14) KFS08190
TNOP=TNOP+SMRM(J,19) KFS08200
TAOSR=TAOSR+SMRM(J,15) KFS08210
TAOSP=TAOSP+SMRM(J,16) KFS08220
TAIR=TAIR+SMRM(J,10) KFS08230
TAIP=TAIP+SMRM(J,11) KFS08240
TXPR=TXPR+SMRM(J,12) KFS08250
TXPP=TXPP+SMRM(J,13) KFS08260
WRITE(NWRIT,920) J, SMRM(J,14), SMRM(J,19), SMRM(J,17), SMRM(J,18) KFS08270
1, AOSR, AOSP, AIR, AIP, STIC, SMRM(J,12), SMRM(J,13) KFS08280
920 FORMAT(2X,I3,9X,F4.0,2X,F4.0,5X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,4X,F9KFS08300
1.1,2X,F9.1,5X,F9.2,4X,F4.0,3X,F4.0) KFS08310
C KFS08320
C STATISTICS RESET KFS08330
C KFS08340
TUNT=0.0 KFS08350
SMRM(J,10)=0.0 KFS08360
SMRM(J,11)=0.0 KFS08370
SMRM(J,12)=0.0 KFS08380
SMRM(J,13)=0.0 KFS08390
SMRM(J,14)=0.0 KFS08400
SMRM(J,15)=0.0 KFS08410
SMRM(J,16)=0.0 KFS08420
SMRM(J,17)=0.0 KFS08430
SMRM(J,18)=0.0 KFS08440
SMRM(J,19)=0.0 KFS08450
KFS08460
KFS08470
KFS08480
KFS08490
KFS08500
KFS08510
KFS08520
KFS08530

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100	CONTINUE	KFS08540
	STAT=NSTAT	KFS08550
	IF (TNOR .GT. 0.0) GO TO 230	KFS08560
	TAOSR=0.0	KFS08570
	GO TO 235	KFS08580
230	TAOSR=TAOSR/TNOR	KFS08590
235	IF (TNCP .GT. 0.0) GO TO 236	KFS08600
	TAOSP=0.0	KFS08610
	GO TO 237	KFS08620
236	TAOSP=TAOSP/TNCP	KFS08630
237	TAIR=TAIR/STIM	KFS08640
	TAIP=TAIP/STIM	KFS08650
	TADMR=TADMR/STIM	KFS08660
	TADMP=TAUMP/STIM	KFS08670
	WRITE(NWRIT,930) TNOR, TNCP, TADMR, TADMP, TAOSR, TAOSP, TAIR, TAIP,	KFS08680
	TIC, TXPR, TXPF	KFS08690
930	FORMAT(' TOTAL',7X,F4.0,2X,F4.0,5X,F7.1,2X,F7.1,4X,F7.1,2X,F7.1,4X,	KFS08700
	F9.1,2X,F9.1,5X,F9.2,4X,F4.0,3X,F4.0)	KFS08710
	TAVCST=(TFC+TIC)/TSOLD	KFS08720
	WRITE(NWRIT,935) TAVCST, NDEFU, SHTR, SHTP	KFS08730
935	FORMAT('/', ' AVERAGE TOTAL CUST',F8.5, ' PER GALLON SOLD',/, ' NUMBER	KFS08740
	1 OF DEFERRED ORDERS',15,/, ' LOST SALES REGULAR',F8.1, ' GALLONS',/,	KFS08750
	2 ' LOST SALES PREMIUM',F8.1, ' GALLONS')	KFS08760
	NDEFU=0	KFS08770
	SHTR=0.0	KFS08780
	STHP=0.0	KFS08790
	RETURN	KFS08800
	END	KFS08810

THE DESIGN OF A REFINED PRODUCTS DISTRIBUTION SYSTEM

by

KARL FRANKLIN STROUP

B. S., Clemson University, 1968

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

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.