A SIMULATION OF THE OIL TANKSHIP MARKET

by

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ABSTRACT

The efficacy of this paper is the development, refinement and programming of the technique of using a simulation model to aid in making the decision of how to fulfill the need for oil transportation from among the available alternatives.

A simulation model of the oil tankship market has been constructed and verbal validation of all the relationships in the model are provided.

Testing of the model for sensitivity to parameters and relationships indicate that the analysis for the above mentioned decision depends heavily on (1) the relationship which determines the spot rate from the utilization of the available supply of tankers, (2) the order policy by which the operatives in the market buy new ships, and (3) the cost of capital used in the analysis.

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All electronic computations were performed at the Computation Center of the Massachusetts Institute of Technology.
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Chapter I

INTRODUCTION

The Spot Market and Its Behavior

Over half of all the merchandise carried by sea consists of petroleum and its products. (See fig. 1) This market for transportation is catered to by tankers, which account for approximately one-third of the total capacity of the world shipping fleet. Companies that produce and market oil are the customers of this transportation service. To insure themselves of sufficient transportation they have developed large marine transportation departments to own and operate their fleets. Historically, the oil companies have tried to own about 50% of their needed capacity, charter on a long term basis another 35% and charter on a short term basis the remaining 15%.

The chartering of this last 15% is preferably done through a limited number of specialized brokers in New York and London who have a considerable knowledge of the oil industry as well as the shipping industry. Knowing this, the owners who have oil tank ships also gravitate towards these brokers.

Because it is difficult to forecast oil demand and, therefore, oil transportation demand, there are large

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2 Ibid., p. 29.
fluctuations in the spot rate at which these tankers are chartered. If at any time there is demand for oil transportation which is equal to 90% of the available capacity (working fleet), and assuming additively that 50% out of the 90% is carried in oil company owned ships, and 35% in long term chartered ships, there remains 5% to be carried in the spot market. In other words, only one third of the vessels in the spot market will be utilized. Now let there be a 10% fluctuation in demand which is not abnormal to 99% of available capacity. Again assuming that 85% of the working fleet is transported by owned and long term chartered ships, 14% will be transported in the spot market. This means that about 93% of the ships on the spot market will be utilized. We see on the basis of this example that a 10% fluctuation in the demand for oil transportation has caused a 60% fluctuation in the demand for spot charter capacity.

As we would suspect from this type of relationship the spot rate fluctuates prodigiously. In figure 2 we show the histogram of spot rates from 1948 to 1965. The rate had a high of about $4.50/1000 ton mile and a low of 50¢/1000 ton miles of oil carried.

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There is a factor of 9 between the bottom and top rates. In this time period extremely high rates occurred three times. The first instance was in 1950, the second in 1951, and the third in 1956 as a result of the Suez Crisis.

Table I gives us an insight into the fluctuations in the cost of carrying oil.

<table>
<thead>
<tr>
<th>Year</th>
<th>Month of Low Rate</th>
<th>Low Rate</th>
<th>Month of High Rate</th>
<th>High Rate</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>August</td>
<td>.90</td>
<td>January</td>
<td>1.33</td>
<td>.53</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>.92</td>
<td>December</td>
<td>3.20</td>
<td>2.28</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>July</td>
<td>1.82</td>
<td>December</td>
<td>4.24</td>
<td>2.42</td>
</tr>
<tr>
<td>1952</td>
<td>December</td>
<td>1.44</td>
<td>January</td>
<td>4.32</td>
<td>2.88</td>
</tr>
<tr>
<td>1953</td>
<td>July</td>
<td>.76</td>
<td>January</td>
<td>1.44</td>
<td>.68</td>
</tr>
<tr>
<td>1954</td>
<td>July</td>
<td>.60</td>
<td>December</td>
<td>1.36</td>
<td>.76</td>
</tr>
<tr>
<td>1955</td>
<td>June</td>
<td>.86</td>
<td>December</td>
<td>2.80</td>
<td>1.94</td>
</tr>
<tr>
<td>1956</td>
<td>March</td>
<td>1.46</td>
<td>December</td>
<td>4.30</td>
<td>2.84</td>
</tr>
<tr>
<td>1957</td>
<td>November</td>
<td>.62</td>
<td>February</td>
<td>4.50</td>
<td>3.88</td>
</tr>
<tr>
<td>1958</td>
<td>April</td>
<td>.59</td>
<td>September</td>
<td>.84</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td></td>
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From observing this table we can also postulate that there are significant savings to be had by knowing how to deal in this market.
Behavior of Operatives in the Market

Little can actually be done to increase tanker capacity in the short run. Ordinarily, it will take about 18 months from the time a new ship is ordered until it reaches the market. Therefore, when a positive fluctuation in demand occurs the price moves upwards. Analysis of previous rate movements indicates that after a certain point (about $1.10/1000 ton miles) the demand becomes very price elastic and this behavior cannot be totally explained by the shifts in the demand schedule. Consequently, it is believed that these patterns are caused by elasticity of expectations. That is, according to this theory once the rates go beyond $1.10/1000 ton miles the owner who wants to charter his vessel behaves as if he believes that the next incremental change in price will be larger than the last. He, therefore, tends to hold his ship off the market, further driving the price upwards.

Once the rates go up, customers, who believe the next change in price will also exceed the last, rush to the market to secure tonnage either before prices explode or before all ships are chartered. Obviously, this also contributes to rising prices and they explode. During the succeeding period both owners and oil companies rush to shipyards to secure additional tonnage. Not only do the oil companies tend to pay exorbitant fees for their spot
tonnage, but also for any long term charters arranged at this time for delivery in the future.

The independent owner hastens to the shipyard somewhat faster than the oil company and so the latter is again stung by having to pay a high price for the ship it builds. From these reactions we can observe that the savings which can be gained from operating with perfect information in this market can be more than just those gained from the timing of spot market purchases. With good forecasts we propose that additional savings can be made in long term chartering and in ship building.

**Purpose of This Study**

The main objective of this study is to use the relationship between the spot rate and the supply and demand for oil transportation, as a basis for forecasting the future level of spot rates.

The future demand for oil transportation can be approximately computed from the forecast for oil demand and the pattern of major international oil movements.

This study develops and explains a computer simulation model of the oil tankship market which is used to develop a time series of spot rates. From the time series of spot rates, the model, by use of further refinements,
indicates the optimal timing for an order for new capacity.

The end purpose of the present effort is to develop a program which will aid an oil company in its decision regarding when it should order new tankers for its own fleet. The strategy that we wish to refine to a workable decision is that of timing orders for new tankers to assure that capacity is available before large rises in the spot market, but yet not so soon that low rates in the spot market cannot be profited from.

Introduction to The Spot Rate Market

In this section we will be concerned with the relationship between the supply and demand for oil transportation and the spot rate at which oil tankers are chartered. We would expect this market to behave as most markets, in the sense that when demand is high and supply is low the price will be high; and when supply is high and demand is low, the price will be low. Besides its similarity to other markets there are some unique aspects of this market which have an effect on how the spot rate moves.

First, the demand for oil and therefore, for oil transportation will not be affected by the price of the oil transported. We believe this assertion to be true because:
a) Short term substitution of sources of energy, other than oil, for oil is limited.

b) Long term substitution of sources of energy, other than oil, for oil is almost non-existent.

c) The marginal cost of the greatest part of all oil produced is very small when compared to its final price. Thus, increases in the price of transportation, which is only part of this marginal cost, will not affect the final cost.

d) The total demand of oil is inelastic with respect to price. (Price fluctuations are caused primarily by independent operators trying to enlarge their own share of the market.)

Second, the supply of oil transportation capacity can only be readily expanded by utilizing vessels in tie-up and vessels idle for over 30 days. To expand the supply any further requires new construction of ships which normally takes about 18 months from the time of order to the time of delivery. For our purpose we may say that after we have utilized all vessels in tie-up no further supply will become available to lower the price which is current in the market, no matter how high the demand for spot charters increases.

1 Z. S. Zannetos, op. cit., p. 35.
Because of these two features in the market we should expect that when supply exceeds demand the rate should be fairly low and remain low. The available ships will be competing for the few ready charters, making the market price low and since the low price will not stimulate demand, these ships will have to continue to compete keeping the market low. When demand grows due to forces external to the oil tankship market the price rises. This rising price tends to increase the supply since owners will be reactivating ships that were tied up. This shifting of the supply function will have an initial softening effect on the price rise in the market caused by the increased demand. However, if the demand continues to rise after the working fleet is at its maximum, then shippers of oil will be competing for a limited supply of ships driving the price high very quickly. Since little new capacity can enter the supply pool, the prices will remain high until either demand shifts to the left, or the orders for new ships, stimulated by the high spot rate, are delivered at a time about 18 months in the future. This is the behavior we expect to find in the market.
The Relationship between Supply, Demand and The Spot Rate

In the preceding paragraph the verbal description of this relationship was given. In the development of the model a quantification of this relationship as well as others will be necessary. Therefore, in figure 3 we show a plot of the index of spot rates versus the ratio of the demand for oil transportation divided by the supply of oil transportation. This ratio is called the supply demand ratio.

Since marginal demand for oil transportation quickly becomes a charter in the market we can estimate the total demand for services by the number of oil tankships operating at any point in time. The total supply is known as the total working petroleum fleet, which is defined as the total fleet less government owned vessels, and those in tie-up or under repair over 30 days.

Observing figure 3 we see that this plot indicates that as the percentage of the fleet in use becomes larger, the spot rate at which a tanker is fixed rises. We may also notice that this function is not linear. By drawing a smooth curve through these data points in the plot and recording the curve we get a table function of the

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1 Ibid., p. 172.
RELATIONSHIP BETWEEN SPOT RATE AND PERCENT OF TANKERS OPERATING

(Figure #3)

SPOT RATE INDEX

$\frac{1}{10^5}$ TON MILES TRANSFORMED

TANKERS OPERATING AS A PERCENTAGE OF WORKING FLEET
relationship. This table function is given in the detailed description of the model later in this paper. A regression line was drawn through these points and is given by the following equation:

\[ \text{% of working fleet in use} = 96.75 - 2.515/x^2 \]

Where \( x \) is the spot rate index.

A comparison of the table used and values which could be derived by means of this equation are also given in the detailed description of the model. The regression analysis pointed out that the spot rate accounted for 83% of the variance in the supply demand ratio. Therefore, it is felt that this curve will give reasonable results for a simulation.

**Relationships Used in the Model**

The simulation model uses a number of relationships. These relationships and their quantification are given in the detailed description of the model. To validate each of these in as much detail as was done for the above relationship would be a very lengthy process and not within the scope of this paper. There is evidence that even the above relationship should be scaled down since the marginal

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2. The model has about 200 such relationships.
vessel in the spot market is now a 40,000 DWT ship with considerably lower operating costs than the T-2, a tanker of about 16,500 DWT, which was the marginal vessel when the above data were compiled.

The efficacy of this paper is in the development and refinement of the technique of using a simulation model to aid in decision making and in providing definitions and verbal validation of all the relationships in the simulation model. Consequently, by testing the model for sensitivity to various relationships we can determine which of these should be investigated further. We have run this model to determine whether it can aid in the decision problem posed and tested it for sensitivity to various relationships. The description of these runs and tests, as well as the results obtained, are given in the final chapters of this manuscript.
Chapter II

DEVELOPMENT OF THE TECHNIQUE OF USING A SIMULATION MARKET FOR MAKING A DECISION IN THE SPOT MARKET

Pictorial Representation of the Technique

Before formalizing the exact decision criteria which will influence design of the model, let us summarize our assumptions about the world. We assume:

a) That the demand for oil transportation and the supply of oil tankers at any instant in time determine a spot rate.

b) That this spot rate, through a feedback system, effects the supply of tankers available at a time in the future; and therefore, the spot rate in the future.

c) That the economics department of an oil company is able to present meaningful forecasts of the worldwide demand for oil and oil transportation, and significant forecasts of that company's demand for oil and oil transportation.

d) That an oil company will pay the current spot rate if it chooses to obtain the necessary transportation from the spot market.

e) That any oil company will pay the current shipyard building cost if it chooses to obtain the necessary transportation by building ships for its own holding.
f) That since both the spot rate and the building cost fluctuate in time, any decision made by analysis of these rates at one point in time may not lead to a good decision.

Given a forecast of the transportation needs of a company and that of the total world, and having compiled the existing supply of tankers, one may use these values to generate time profiles of both the spot rate and the cost of building new ships. Knowing these time profiles one may then analyze these costs in conjunction with the given time profile of needs, to determine which one of the various alternative ways of providing the transportation has the least cost. (This system is pictorially shown in figure 4.)

The Exact Question the Model will Answer

An oil company may transport oil in any manner of three methods. By the first method the oil company will buy and operate new ships. Using the second method it will charter ships on a long term basis from another owner for a period exceeding one year. Finally, by the third method it will charter ships for one voyage at a time from other owners through the spot rate charter market at the going rate.

In this model, which is an aid to the decision regarding which method oil should be transported, I have limited for consideration alternatives #1 and #3 above. That is, the model only considers whether a company should build a ship or continuously charter on the spot market.
SUPPLY
available oil tankships

INPUT # 1:
demand for oil transportation (worldwide)

SPOT RATE
at which oil tankships are chartered

FEEDBACK SYSTEM
which determines the supply at a later time

cost to build new ship

INPUT # 2:
forecasted oil transportation demand for a hypothetical oil company

ANALYSIS
of alternative decisions that the oil company can make with regard to how to supply the necessary transportation

THE BASIC MODEL
(figure # 4)

OUTPUT:
least cost method to supply the necessary transportation
After deliberate thought it was decided to design the model to answer the following question: "What is the least expensive alternative for transporting our expected demand for the next three and a half years, considering that we may order a ship during any month from the present and ending two years from now?"

We only consider the possibility of ordering the ship during the first two years of the three and a half year period because there normally is a delay of about 18 months between the time a vessel is ordered and the time it is delivered. Accordingly, a vessel ordered in the last 18 months would not be delivered during the period of our analysis and is not considered.

The question arises as to how far into the future we should project our forecast. It is a known fact that an oil company does not build a ship to last only three and a half years; but to last 20 or more years. The three and a half year term was chosen for the following reasons:

1) This period represents the extent of a decent forecast.

2) This period limits the amount of computation time including programming, necessary to develop the simulation.

3) We will be able to compare the costs of each alternative in two ways: First, we will take the actual costs incurred every month for operating expenses,
exclusive of capital costs, for the ship delivered, and the costs from the spot market, compound these costs to a final value, then find an equivalent monthly cost which will give this value. To this equivalent cost we will add a 20 year equivalent monthly capital cost of the ship which will be the cost of a 20 year annuity equal to the ship's cost less the present value of its depreciation tax shield and salvage value. Secondly, we can readily determine what each ship saved the oil company monthly when it was operating from having to obtain transportation from the spot market. Compounding these savings to month 42, and subtracting them from the equivalent monthly payment for operating and capital expenses, required for the ship gives the average long term charter rate the oil company would have to receive for the remaining life of the ship in order to break even. The lower the long term charter necessary will mean in comparison that one ship is more advantageous than another to build.

4) Considering the stratagem of "3" above, we want a forecast of long enough duration to make such a comparison meaningful. We feel that such an analogy will be significant for a three and a half year forecast because historically large peaks in the market have lasted no longer than one year. (See fig. 2) By testing this model periodically, we should be able to detect these peaks in
due time and act accordingly; however, an improvement would be to program the model to simulate a period long enough to cover the average duration between peaks. Peaks are noteworthy because by timing delivery just before a peak we will receive a high average rate for the first months operation which necessarily gives a lower average break even rate for the rest of the ship's life. The break even rate is that which will just pay our capital costs and operating costs of the ship over its life, and leave a return after taxes of a specified percent.

The alternatives are also defined further and hence limit the question the model answers. First, the alternatives occur in a monthly time frame. That is, we will either order our ships in month X or delay ordering until month X plus 1; the model will not consider ordering in month X plus \( \frac{1}{2} \). The size of the ship or ships ordered is another consideration since at different times we will be able to build different total capacities. For the model I have chosen to order capacity totaling 80% to 90% of expected demand 18 months in the future of the ordering date. These alternatives may be represented graphically and are in figure 5.

\[1\)
Simulation runs may be made for various values of specified parameters.
EXPLANATION OF ALTERNATIVES

(figure # 5)

time profile of forecast for oil transportation

order #2

order #12

delivery of order #2

delivery of order #12

TIME

(months)

RELATIONSHIP BETWEEN FORECAST AND ACTUAL DEMAND

(figure # 6)

forecast

forecast + a random element used to evaluate alternatives

TIME
The 24 alternatives which we choose to compare are those of ordering a ship in any one of the 24 months starting from the present. In figure 5, alternatives #2 and #12 are graphically represented. Alternative #2 states that we will order a ship or ships of size .8xD$_1$ (where D$_1$ is the expected demand at month 20), at month 2 for receipt at month 20. From month 0 to month 20 we will continuously charter on the spot market for our demand. After month 20 we will transport .8xD$_1$, by using our ship and any excess continuously through the spot market.

The twelfth alternative says that we will order a ship or ships of size .8xD$_2$ (where D$_2$ is the expected demand at month 30) at month #12 for delivery at month 30. From month 0 to month 30 we will transport .8xD$_2$ in the delivered ship and any excess through the spot market until month 36. The other 20 alternatives are similar, only the orders will be made in different months.

The Analysis of Alternatives

We have used our forecast demand in determining the size of ship ordered. However, the actual costs incurred will be based on a different time profile. By adding a random element with a specified variance to the forecast, we can generate a second time profile which we shall call the demand used to evaluate the alternatives. In figure 6
we can see a representative difference between the forecast and the profile used for cost analysis.

When we evaluate an alternative we will use this randomized demand curve to obtain the amount of transportation needed. By running the model without the random element and then running it a number of times with different random noise of the same variance we can determine the effect of such a random element in the market place on our analysis. For the amount obtained from the spot market we will use the spot rate at the time the demand is needed. For the new buildings we will use the price of ship-building generated by the system, with operating and capital costs consistent with present prices. All costs will then be discounted to present value and then expanded into an equivalent monthly cost so that the alternatives may be compared.

Even though this model gives only a local optimization in that we are dealing with a small segment of future time, it is felt that the policy of using this model to determine by what method to transport oil, will give answers which will be less expensive than a policy which forecasts demand, then specifies building for company ownership Y% of this forecast and obtaining (100-Y%) continuously from the spot market. The basic difference between the policies is the fact that under the former, the per cent of the
company's need for oil transportation that it can provide by owned tonnage varies over time, more so, than if the latter policy is used. Under the policy of using the model as an aid to the decision, we will own or charter depending on our forecast of which will cost less. If during one period it will be less expensive to own ships we will buy them and the percent of oil transported on owned vessels will rise. At other times it will be less expensive to roll over the spot market and procure as much of their transportation needs from spot charters as possible. In this situation the percent of oil transported on owned ships will decrease. Under the second policy, where we order ships to be able to transport Y% of our forecast, the only variance in the percent of oil transported by owned vessels will come from variance within the forecast. That is, if our forecast is higher than actual demand the percent of oil transported in owned ships will rise and if the forecast is lower the opposite will occur.

The Simulation Model, Introduction to the Model

The model which we have developed, even though it does not cover every detail, is complex and requires many computations. Therefore, it would be a horrendously large task to try to hand calculate all of the equations. Hence, this model must be programmed for use on an electronic
computer. A program is a procedure for converting some sort of data into desired results. As such, it can be expressed in any one of a number of programming languages, which may be recorded on one of the available mediums, such as magnetic tape or punched cards.

The "Dynamo" language is one such computer language which translates mathematical models into tabulated and plotted results. Since this language has built into it the concept of a feedback system (our model is based on the premise that there is a feedback system, that the spot rate affects future supply which in turn affects the spot rate), and since Dynamo is continuous in time (our model deals with the time profile of the elements in the system), we have chosen Dynamo to be the language of our simulation.

This model shown in figure 7 says that the spot rate determines world policies of the present and future owners of oil tankers. These policies determine the orders for new ships which affect the supply of oil tankers in the long run, starting about 18 months later. The amount of orders also affects the price of ships, which also influences the policies of owners. The policy of owners affects the supply of ships, in the short run, by determining the retirement rate, the tie-up rate, the number of vessels under repair, and the returning of vessels to the market.
MODEL OF THE FEEDBACK SYSTEM

(figure # 7)
from tie-up. The supply of vessels affects the spot rate, completing the feedback system.

In the succeeding four chapters we will completely explain this model, as well as the program for comparing the different alternatives described previously.
Chapter 3

THE SIMULATION MODEL

Detailed Description of the Market Sector

In this chapter we will describe the formulation of the sector in the model which converts the forecast of the demand for oil to a demand for oil transportation. This demand is then related to supply and the spot rate is determined. Finally the spot rate is used to generate a world-wide policy index which affects the order rate for new buildings.

Orders for new buildings in conjunction with the capacity available in shipyards to build ships are used to determine the price for new buildings. The price of new buildings in turn affects the decision to order new ships. (This is shown pictorially in fig. 8.)

Starting with the upper left corner, the demand for oil, an exogenous input, is introduced into the model by the following:

\[
DEML.K = DEMA.K + DEMB.K + DEMC.K
\]

DEML = Total demand for oil
DEMA = Average demand for oil
DEMB = Random demand for oil
DEMC = Seasonal demand for oil

The above states that the total demand has been broken down into an average, a random and a seasonal
THE MARKET SECTOR

(figure # 8)
component which are summed to give the total.

The first component of demand, DEMA, consists of the average monthly demand for oil. This demand is represented by the following equation:

\[ \text{DEMA}_K = \text{RAMP} (\text{OINA}, 0) \]

DEMA = Average monthly demand
OINA = Average monthly increase in demand
RAMP = Equation type which adds the average increase in demand to the present demand each time interval
That the model is simulated

This equation says that the average demand at any time is equal to the present demand plus the average increase in demand per unit time. At the start of the simulation we must specify the present demand as well as the average increase. This is done by:

\[ \text{DEMA}_K = \text{PRES} \]

CINA = \( (\text{PRES})(\text{OINB}) \)
OINB = \( (\text{GRO})/(12) \)

PRES = The present demand for oil
OINB = The % increase in demand for oil per fraction of a month
GRO = The % increase in demand for oil per year
DT = The fraction of a month which represents the time interval between each simulation of the model

The average growth rate projected for the next five years in the oil industry is 6.3%. The average

\footnote{1}{Interview with Mr. G. Ballow, Assistant Vice President, Economics Department, Standard Oil Company of California, March 27, 1967.}
demand for oil in 1966 was 15,532,000 barrels per day, equivalent to 69,700,000 tons/month. We therefore specify for the initial condition of our simulation model:

\[
\begin{align*}
\text{PRES} & = 69.7 & \text{10}^6 \text{ tons/month} \\
\text{GRO} & = 0.003 & \text{Dimensionless}
\end{align*}
\]

Before considering the other two components of the demand for oil let us formulate the conversion from demand for oil to demand for oil transportation. We have used the international oil movements as shown in figure 9 and compiled in table 2 to develop a factor to convert tons/month demand for oil into ton-miles/month demand for oil transportation. From the calculations in table 3 we will take this factor to be 2920 miles. If we then multiply this factor by the demand for oil we will find that in 1966 the industry had to provide 203,800,000,000 ton miles/month carrying capacity.

The gross registered tonnage of tankships in 1965 was 54,864,000 tons and if we consider them to be approximately 40.2% efficient then these ships must move on the average of 9,280 miles/month. At 720 hours/month this equals 12.89 knots, which means the approximation is reasonable.

---

1 Organization for Economic Cooperation and Development, \textit{op. cit.}, p. 75.
2 Supplied by the Economics Department, Standard Oil Company of California.
3 Assumes 6.77 barrels/ton for oil.
4 Organization for Economic Cooperation and Development, \textit{loc. cit.}
5 Z. S. Zannetos, \textit{op. cit.}
MAJOR INTERNATIONAL OIL MOVEMENTS

FIGURE #9
### Table 2: Major International Oil Movements

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### Table 3

1966 WORLD OIL MOVEMENTS

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<th>From</th>
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<th>Barrels/Day</th>
<th>Barrel Miles/Day</th>
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*Indicates major oil movement.
Table 3 (continued)  

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<th>Barrels/Day</th>
<th>Barrel Miles/Day</th>
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</table>

: each barrel moves ________ miles  2920

(1) The amounts and places come from Table 2
(2) The distances are approximated from an almanac using principle oil ports of the world, as obtained from C. H. Cufley, op. cit., pp. 395-6.
The random component of demand is defined by:

\[ \text{DEMB}_k = (1)\text{NORMRN}(0, \text{DEVIA}) \]

\text{DEMB} = \text{Random component of demand.}
\text{NORMRN} = \text{The equation type which generates random numbers with mean 0 and standard deviation, DEVIA.}
\text{DEVIA} = \text{Standard deviation of the random component of demand.}

The random portion of demand has a mean of zero and the random numbers will have STD deviation which we can specify. We intend to examine the behavior of our model for random demand of different standard deviations. For this illustration we have set the standard deviation at 5% of the present demand for oil. By:

\[ \text{DEVIA} = (\text{PRES})(\text{DEVIB}) \]
\[ \text{DEVIB} = .05 \]

\text{DEVIB} = \text{STD deviation of demand stated as a per cent of current demand.}
\text{PRES} = \text{Present level of demand.}

The seasonal fluctuation of demand has been set equal to a sine wave with a period of twelve months.

\[ \text{DEMC}_k = (\text{AMPL})\text{SIN}(2\pi)(\text{MNTH}_k)/12 \]

\text{DEMC} = \text{Seasonal component of demand for oil.}
\text{AMPL} = \text{Amplitude of the seasonal variation.}
\text{SIN} = \text{Equation type which generates a sine wave.}
\text{MNTH} = \text{Time at which fluctuation is at peak.}
12 = \text{Period of seasonal fluctuation in months.}

The amplitude of the seasonal variation is then specified at 10% by:

1

Interview with Mr. M. Sawyer, Marine Transportation Department, American Oil Company, February 1, 1967.
AMPL = (PRES)(AMPB)
AMPB = .10

AMPL = Amplitude of seasonal fluctuation as a per cent of present demand.
PRES = Present level of demand for oil.
AMPL = Amplitude of seasonal fluctuation as an amount of demand.

Finally, the timing of the seasonal fluctuation is controlled by regulating the peak of the amplitude in time. This is done by:

MNTH.K = TIME.K + SESN
SESN = 3

TIME.K = A function in the Dynamo language which keeps track of time during the simulation run.
SESN = A constant which in this case moves the peak three months to the right.

Previously we computed an average distance over which oil is transported. This distance is now used to convert demand for oil to demand for transportation by:

DEMT.K = (DEML.K)(2920)/EFF

DEMT = Demand for transportation
DEML = Demand for oil
EFF = Efficiency of a tanker. This figure adjusts for a tanker's ballast voyage and port time.

The demand for transportation is equal to the average monthly demand for oil, times the number of miles each ton of oil must travel, divided by the efficiency that a tanker's capacity, measured in miles/month, can be used. We have taken the efficiency figure to be 40.3% and have specified it by:
EFF = .403

The demand for transportation is then transformed into an amount of ships operating. This is done by:

\[ \text{COSC}_K = \text{COSC}_J + (DT)(1/\text{TTSC})(\text{DEMT}_J - \text{COSC}_J) \]

\text{COSC} = \text{Capacity of tankships operating}
\text{DEMT} = \text{Demand for transportation}
\text{TTSC} = \text{Time to charter a ship}

This equation simply says that capacity operating in time $K$ is equal to the capacity operating in the previous time interval, plus a fraction/the difference between total demand and the capacity now operating. The fraction of this difference to be added is determined by dividing the interval of time over which the calculation is made by the average time necessary to charter a ship. Initially we set the values of the variables in the above equation as follows:

\[ \text{TTSC} = .2 \quad \text{Months} \]
\[ \text{COSC} = 69.7 \times 2920/ .403 = 10^9 \times \text{ton/miles month} \]

The initial value for the ships now operating is simply the amount of oil demanded multiplied by the factors previously discussed.

The next step is to relate the amount of ships in operation with the total capacity of ships available to
transport oil. With regard to the discussion in chapter II, that the spot rate is determined by the ratio of tankships in operation to the total available; we determine this ratio by:

\[
SDR.K = \frac{COSC.K}{SUPLY.K}
\]

**SDR** = Supply demand ratio  
**COSC** = Capacity of ships operating  
**SUPLY** = Supply of ships available (Formulated in Chapter IV)

From this ratio we formulate the spot rate using a table function based on figure 3. (See page 19) This is the spot rate at which we expect the next ship to be chartered. It is represented by:

\[
EQPCH.K = TABHL(TBEQP,SDR.K,.8,.97,.01)
\]

**TBEQP** = .62/.62/.62/.625/.63/.66/.70/.76/.85/.95/1.05/1.17/1.35/1.53/1.80/2.15/2.80/4.30

**EQPCH.K** = The spot rate index in \$/1000 ton miles  
**TBEQP** = Table to determine spot rate from per cent of supply that is chartered.\(^1\)  
**SDR** = Supply demand ratio

The published spot rate, the rate at which the last charter was fixed, and the rate used by operatives in the market to form policy, is determined by:

\[
PRCH.K = PRCH.J + (DT)(1/TPCH) (EQPCH.J-PRCH.J)
\]

**PRCH** = Published charter rate  
**TFCH** = Time to publish the charter prices  
**EQPCH** = The spot rate index

\(^1\) See figure 10, page 50, to compare this table with the previously discussed regression curve.
This equation says that the published rate is:

The last published rate plus the difference between the spot rate index and the last published rate divided by the time needed to publish the rate. For the first run of our simulation we will set the spot rate index at the level of December 1966, about 1.00/1000 ton miles and the time necessary to publish the spot rate index at one month.

The required equations are:

\[
\begin{align*}
\text{PRCH} & = 1 \\
\text{TPCH} & = 1
\end{align*}
\] 

$/1000 \text{ ton miles} \\
\text{month}

The spot rate at which tankers are hired has a profound effect on operators in the market and motivates them to take action in different ways. When the spot rate is low there are more ships around than charters, therefore, very few owners want to order new capacity or reactivate tied up ships. Then as spot rates rise entrepreneurs rush to the shipyard to secure a ship on order and thereby charter it at a high rate. Later in the description of the model we will determine the amount of new orders, tie ups and retirements. These variables can be represented as a function of a world-wide policy index which we can define by the following equation:

\[
\text{WWPI}.K = \text{TABHL(TBWW,PRCH}.K/, 5, 4, 5,.5)
\]

WWPI = World wide policy index
TBWW = Table to determine the world wide policy index
PRCH = The published spot rate
A low number of this index represents relatively few orders for new tankers, large number of layoffs, and a large number of vessels under repair. A larger index number indicates that decision makers are ordering a high number of new ships and are reactivating as many ships as possible. Graphically this index, as a function of the spot rate, is shown in figure 11. The exceedingly steep slope in the range of $1/1000 ton miles for the spot rate, represents the actions of speculators who operate in the market when rates are at this level. For example, when the rate goes above $1/ton miles, owners increase orders to the shipyards very promptly. As the rate increases these orders continue at a high level, but the increase tapers off as the value of readily procuring a ship on order diminishes. This index represents what we consider behavior in the real world to be. By changing this table to reflect possible other patterns of reaction and then resimulating the model, we can analyze the effects in the spot rate due to different behaviors.

The first decision, which is affected by behavior patterns of operators in the business, is that of ordering new ships. Let us represent the resolution to order ships as a summation of three separate functions. The first function is dependent upon the world-wide policy index, the difference between the present demand for tankers, and the
supply available, and a factor representing the cost of
buying new capacity; the second is dependent on the growth
of world-wide oil demand and the third is dependent on
the aging of the present supply of tankers. The equation
depicting this is:

\[ DEC.K = (WWPI.K)(DIFFR.K)(CDEC.K) + (GRO)(.083)(SUPLY.K) + (.0042)(SUPLY.K) \]

CDEC = A factor dependent on the present cost of ships
and a scaling factor for our world-wide policy
index.
DEC = Amount of capacity that has been decided to be ordered.
DIFFR = The difference between the present demand for oil
transportation and 92% of the present supply.
GRO = The yearly growth rate of world-wide oil demand.
.083 = A conversion factor equal to 1/12 which converts
the above yearly growth rate to a monthly growth rate.
.0042 = A factor representing 1/20 years 12 months year which
is the approximate number of ships being retired
each year.

This equation indicates that the decision as to
the amount of new building is equal to the summation of:
(1) the product of the difference between the demand and 92%
of the supply, a factor dependent on the present cost of
ships and the world-wide policy index; (2) the product of
the growth rate per month and the present supply of tankers;
and (3) the product of the present supply of tankers and
the fraction of tankers which would be retired each month if
the maximum useful age of tankers is 20 years and that the
age distribution is uniform.

The factor, DIFFR, is specified by the following
equation:
DIFFR.K = DEMP.K - (.92)(SUPLY.K)

DEMP = The demand for oil transportation.

The reason why we chose to take the difference is between demand and 92% of supply/that whenever the demand becomes greater than 92% of supply, the spot rate rises quickly and therefore, we suspect that operators will order ships until the spot rate decreases below that determined by the demand equalling 92% of the supply.

The factor, CDEC, is specified by:

CDEC.K = (CONST)(PPSU.K)

CONST = A factor used to manipulate the world-wide policy index in different simulations.
PPSU.K = A factor dependent on the present cost of ships.

This factor is the product of a factor dependent on the price of ships and a constant. This constant is initially at .275.

CONST = .275

At an average spot rate of about 75¢/1000 ton miles the data observed\(^1\) show orders to be about zero. Setting the factor CONST equal to .275 will make orders approximately zero at the given spot rate.

\(^1\) Z. S. Zannetos, *op. cit.*, p. 93.
Since all owners in the tanker industry are affected by costs, we have defined a factor (PPSU) which will represent the percentage of orders, that they can order because they will be restricted by cost considerations.

This is defined by:

\[ PPSU.K = \text{TABHL}(TBPPS, PRSH.K, 7.0, 8.8, .3) \]
\[ TBPPS = .98/.99/1/.98/.9/.84/ .8 \]

PPSU.K = Factor dependent on the present cost of ships which affects the decision to tender new orders.
TBPPS = Table to determine the above factor from the price of new buildings.
PRSH = The published price of new buildings.

Graphically, this curve is represented in figure 12.

We have represented two phenomena in this table. First, as the price of building ships rises, owners increase the amount of present orders because they believe that the future price will be higher than the present price. This inter-period substitution of orders takes place in the first third of the price range. In the left two-thirds of the range, orders decrease with price representing the phenomenon in companies, of a capital budgeting review, whether formal or informal, for an expenditure of money for a ship. In an oil company the marine manager will propose buying certain capacity or a number of ships. If the price is suitable, and the company has the cash necessary, this will be approved in full, However, if the price is high, the order will be lowered due to cash restrictions.
These decisions to order new capacity become orders to the shipyard after a delay in which negotiations over price and design details occur. The order rate is determined by the following equation:

\[
\text{ORDER}.KL = \text{DELAY } 3(\text{DEC}.K, \text{TDEC})
\]

\[
\begin{align*}
\text{ORDER} &= \text{ORDER rate to shipyard for building new ships.} \\
\text{TDEC} &= \text{Time to negotiate particulars of the orders.}
\end{align*}
\]

The time needed to negotiate details of the new building is estimated to be about two months.

\[
\text{TDEC} = 2 \text{ months}
\]

The order rate is used as an input to the shipyard sector, as described in Chapter V. It is also used to determine a first approximation of the price of new buildings.

\[
\text{PRICE}.K = \text{TABHC} (\text{TBICE}, \text{ORDER}.JK, 0, 20, 2)
\]

\[
\begin{align*}
\text{PRICE} &= \text{First approximation of price of new shipping capacity in $1000 ton miles/month capacity.} \\
\text{TBICE} &= \text{Table to determine price.} \\
\text{ORDER} &= \text{Order rate of new buildings.}
\end{align*}
\]

The table (TBICE) which is used to determine the first approximation of the price of new ship buildings is shown in figure 13.
This function is the one which would determine the price of ships from demand alone. When demand is high the ship operators are willing to pay more, and the shipyards insist on a higher price. When the order rate is low the reverse occurs.

The actual price of ships is determined by a combination of the demand and supply aspects of the market. The actual price is determined by:

\[ EQPSH.K = (FACTOR.K)(PRICE.K) \]

- **EQPSH.K** = Actual price of new ship.
- **FACTOR.K** = A factor developed in the shipyard sector of the model which is determined by the amount of business the shipyard is doing.

This equation combines both the supply factor and the demand price into the actual price of the current new building. This price will be published after a delay, a similar phenomenon to the published price of spot charter fixture, and this price, rather than the spot price is used by the operators in the market to decide the factor dependent on the present cost of ships which affects the decision to tender new orders (PPSU). The appropriate equation is:

\[ PRSH.K = PRSH.J + (DT)(1/TPSH)(EQPSH.J - PRSH.J) \]

- **PRSH** = Published price of new buildings.
- **TPSH** = Time to publish the prices of new buildings.
- **EQPSH** = The current price of new buildings.
The published price is equal to the last published price plus the difference between the published and the current prices divided by the time to publish. Initially, we set PRSH at about $7.8/1000 ton miles/month of oil transported.

\[
\text{PRSH} = 7.8 \quad \text{\$1000 ton miles}
\]

In 1966 the cost of building a new 100,000 DWT tanker of 16 knots speed was approximately $90/DWT. At 16 knots and 720 hours/month we are then paying $90 for each DWT to move 11,500 miles per month or $7.8/DWT to move 1000 miles/month. That is how the above figure was derived.

This concludes the development of the Market Sector of our model. The spot rate (EQPCH) and the actual price of a new ship building (EQPSH) will be used in the Analysis Sector, chapter VI. The world-wide policy index (WWPI) will be used in the Capacity Sector, chapter IV, and the order rate (ORDER) will be discussed in the Shipyard Sector, chapter V.

Up to this point we have brought together the demand for oil, an exogenous input, with the supply of ships from the Capacity Sector, determined a spot rate for chartering ships, the order rate for new ships, and an approximate price of new ships.

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1 See figure 14. This figure was supplied by the Esso International Oil Company, Department of Marine Transportation.
Chapter IV

THE SIMULATION MODEL

Detailed Description of the Capacity Sector

In this chapter we describe how the production rate of new capacity from the Shipyard Sector becomes part of the total supply of tankships, how this supply is modified by tieups and vessels being scrapped and finally, develop the amount of supply available to the spot market at any point in time. This sector is shown graphically in figure 15.

In specifying the supply of capacity to be used in our determination of the spot rate we must be careful to insure that it is a meaningful figure. The figure we choose to use is the working fleet. The working fleet is the total fleet available less tieups, vessels idle over 30 days and government and special purpose vessels. We know that the supply curve, or the amount of vessels in the working fleet can change within limits very suddenly, by owners reactivating tied up ships, and completing repairs rapidly. In this sector of our model we develop the mechanism of equations which will do precisely what we have defined above.

Starting in the upper right corner of figure 13 is the value for the total supply (SUPLY.K) which will be
THE CAPACITY SECTOR

(figure # 15)
used to determine the spot rate in the Market Sector of our model. This value is equivalent to the sum of five components by age of the total fleet, less tieups, ships idle over 30 days and ships under repair over 30 days (tieups). The appropriate equations are as follows:

\[ \text{SUPL}_K = \text{F100}_K + \text{F105}_K + \text{F10L}_K + \text{F1L5}_K + \text{F20}_K + 0 \]
\[ \text{SUPLY}_K = \text{SUPL}_K - \text{TIUPS}_K \]

\text{SUPL}_K = \text{Total supply of ships which can be used for operations}
\text{SUPL}_K = \text{A convenience variable equaling total supply plus tieups.}
\text{TIUPS} = \text{Vessels idle or in repair over 30 days and tieups.}
\text{F100} = \text{Component of fleet 0-5 years old.}
\text{F105} = \text{Component of fleet 5-10 years old.}
\text{F10L} = \text{Component of fleet 10-15 years old.}
\text{F1L5} = \text{Component of fleet 15-20 years old.}
\text{F20} = \text{Component of fleet over 20 years old.}

The components of the total fleet by age are determined by the following equations:

\[ \text{F100}_K = \text{F100}_J + (\text{DT})(11)(\text{PR.JK}+0)+(160)(\text{F100}_J) \]
\[ \text{F105}_K = \text{F105}_J + (\text{DT})(160)(\text{F100}_J - \text{F105}_J) \]
\[ \text{F10L}_K = \text{F10L}_J + (\text{DT})(160)(\text{F105}_J - \text{F10L}_J) \]
\[ \text{F1L5}_K = \text{F1L5}_J + (\text{DT})(160)(\text{F10L}_J - \text{F1L5}_J) \]
\[ \text{F20}_K = \text{F20}_J + (\text{DT})(160)(\text{F1L5}_J + 0) + (-11)(\text{SCRAP.JK}+0) \]
\[ \text{PR.JK} = \text{The production rate of new ships; this rate is developed in the Shipyard Sector.} \]
\[ \text{SCRAP.JK} = \text{The scrap rate of ships over 20 years old.} \]

Each of these equations say that the component of the fleet is equal to the component of the fleet in the last time interval plus the rate of change per unit time multiplied by time. For the component of age 0-5 years the
incoming rate of change is the production rate for the shipyards. The outgoing rate is the rate at which ships in this component age beyond five years. It is assumed that the distribution of age within each of the age components is uniform. Therefore, in each case the outgoing monthly rate of change is $\frac{1}{60}$ (12 months x 5 years) of the present level. For the components between five years and 20 years the rates of change are only those due to age. However, in the component which represents ships over 20 years the outgoing rate is the rate of scrapping of old vessels.

Initially, all of the components of the total fleet must be specified. The level of each of these components in the year 1965 was as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>238</td>
<td>231</td>
<td>133</td>
<td>35</td>
<td>63</td>
</tr>
</tbody>
</table>

These levels have been determined by allocating the total figure for 1965 by the volumetric age distribution as follows:

Table 4

AGE DISTRIBUTION OF TANKERS

<table>
<thead>
<tr>
<th>Age of tankers (years)</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20 up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per cent of total tonnage</td>
<td>34%</td>
<td>33%</td>
<td>19%</td>
<td>5%</td>
<td>9%</td>
</tr>
</tbody>
</table>

The rate at which ships are scrapped, broken up, or lost is determined by the following:

\[
\text{SCRAP,KL} = \frac{(FL20,K)(SAY,K)}{12}
\]

\text{SCRAP} = \text{Amount of capacity to be scrapped per month,}
\text{FL20} = \text{The component of the total fleet over 20 years old.}
\text{SAY} = \text{Yearly per cent of capacity over 20 years old to be scrapped.}

The scrap rate is the yearly percent of capacity to be scrapped times the capacity over 20 years old, divided by 12 to convert to a monthly rate. The percentage of old capacity to be scrapped is dependent upon the world wide policy index. If the index is high the rate will be low and vice versa. The equations which determine the percent of capacity to be scrapped are:

\[
\text{SAY,K} = \text{TABHL(TLYUP,WWPI,K,0.1.2.1)}
\]

\text{/001/.00}\\

\text{SAY} = \% \text{of old vessels to be scrapped yearly}
\text{TLYUP} = \text{Table to determine "SAY".}
\text{WWPI} = \text{World-wide policy index.}

\footnote{Organization for Economic Cooperation and Development, \textit{op. cit.}, p. 73.}
Graphically, this is represented in figure 16. This table has been derived from a correlation of data which relates tieups to the spot rate. The scrapping rate in 1965 was $4 \times 10^9$ ton miles/month capacity. In this model if the spot rate index is $75/1000$ ton miles the world-wide policy index will be 1.0 and the percent per year to be scrapped will be 7%. If the capacity of ships over 20 years old is $63 \times 10^9$ ton miles/month as given in an initial condition, the lay up rate per month will be $6 \times 10^9$ ton miles/month. This relationship should be approximately right since the figure generated by the model approximates the 1965 figure for the world.

We also determine the tie up rate from this same table. In this case, the monthly amount of vessels in tieup will be a function of the total fleet, and the world-wide policy index as expressed in the following equation:

\[
\text{TIUPS.K} = (\text{SUPLY.K})(\text{SAY.K})(\text{ADJ})
\]

TIUPS = Amount of capacity idle or in repair over 30 days or tied up.
SUPLY = Total supply of tankships.
ADJ = An adjustment factor

By setting our adjustment factor at 1.0, supply at $700 \times 10^9$ ton miles/month capacity and using the scrapping rate as above equal to 0.07, then tieups determined by our model when the spot rate index is $75/1000$ ton miles

---

1 Z. S. Zannetos, op. cit., p. 156.
transported, is $25 \times 10^9$ ton miles/month capacity in layup. This is 3.6% of the total fleet at initial conditions.

This figure also agrees with 1965 figures of $3.53 \times 10^9$ ton miles/month in tieup plus $12.2 \times 10^9$ ton miles/month capacity in the grain trade giving a total tieup + tankers in grain trade of $15.7 \times 10^9$ ton miles/month capacity.\(^1\)

We have completed the description of this sector. The supply of tankship capacity developed is used in the Market Sector to determine a spot rate. In the next chapter we will develop the process which goes on in the shipyards of the world and which determines the production rate which allows new capacity to flow into this sector.

Chapter V

THE SIMULATION MODEL

Detailed Description of the Shipyard Sector

In this chapter we model the way orders from the Market Sector are channelled through the shipyards of the world and after a total delay of about 18 months are delivered through a production rate as new capacity. The percent of maximum production capacity that shipyards are utilizing is also calculated and this is fed back to the Market Sector to help determine the price for new ships. It is sent to the Analysis Sector to help determine the length of time needed between order and delivery of a new ship. Pictorially this model is related in figures 17A and B.

Starting at the upper right of figure 17A, orders for new ships are accepted by the shipyards of the world. From the value of these orders the managers of the shipyards vary the production level in the shipyards and the flow of ships into the working fleet.

The only input to this section is the order rate. As orders are received they are accumulated by the following:
THE SHIPYARD SECTOR

(figure # 17A)
THE SHIPYARD SECTOR

(figure # 17B)
\[ \text{TOO}_K = \text{TOO}_J + (DT)(\text{ORDER}_J - \text{PR}_J) \]

\[ \text{TOO}_K = \text{Tonnage on order in the shipyards. (Tons)} \]
\[ \text{ORDER} = \text{Order rate. (Tons/Month)} \]
\[ \text{PR} = \text{Production rate in the shipyards. (Tons/Month)} \]

In other words the tonnage on order or under construction is equal to the tonnage on order or under construction previously plus the orders coming in, less the production going from the shipyard. If the order rate equals the production rate, the level of construction in the shipyards will be in equilibrium. Therefore, our initial conditions were set so that the production rate does equal the order rate. In the six months from July 1, 1966 to December 31, 1966, 6,188,486 DWT were delivered, and 4,158,411 tons from January 1, 1966 to July 1, 1966. These figures are comparable to 11.3 and 7.4 respectively. (All figures in $10^9$ ton miles/month capacity.)

The tonnage on order and under construction at the end of 1965 was 11,660,000 DWT on $133 \times 10^9$ ton miles/month capacity. If we assume that an equal amount of this will be finished in each of the next 18 months we also get the production rate equaling $1/18$th of this or $7.4 \times 10^9$ ton miles/month. From the above we get initially:

\[ \text{TOO}_K = 133 \quad 10^9 \text{ ton miles/month} \]

---

Ships under construction in a shipyard are normally equal to the tonnage on order. As long as the order rate equals the production rate this condition will remain. Only when there is an imbalance between these two rates will tonnage on order and ships under construction change. Before we describe the model of the mechanism of change let us formulate the level of the ships under construction.

\[ SUC_K = SUC_J + (DT)(ASYC_{JK}-PR_{JK}) \]

\( SUC \) = Ships under construction.
\( ASYC \) = Rate of addition to shipyard capability.
\( PR \) = Production Rate.

The ships under construction at any time are equal to the ships under construction in the previous time plus the difference in the additions to shipyard capacity and the production rate in the length of time between the two times. At equilibrium additions to shipyard capability will equal the production rate and, therefore, ships under construction will remain at the same level. This level then determines the production rate by:

\[ PR_{KL} = \frac{(1/TTSC)}{(SUC_{K}+0)} \]

\( TTSC \) = Time to construct a ship.

Initially, we set ships under construction equal to the tonnage on order, and the time to construct a ship at 18 months.
TTSC = 18
SUC = 133

The initial production rate will then be $7.4 \times 10^9$ ton miles/month equal to the delivery rate between January and July 1966.

If the order rate does not equal the production rate then the rest of this sector comes into play. Now let us define yard capability which, initially, we will set equal to both tonnage on order and ships under construction.

\[
YC_K = YC_K + (DT)(ACSCJK+0)
\]

\[
YC = 133
\]

YC = Yard Capability.
ACSC= Additions to shipyard capability.

To alter the shipyard capability first we compare the tonnage on order to the present yard capability to get an order capability ratio.

\[
OCR_K = TOO_K/YC_K
\]

OCR = Order capability ratio
TOO = Tonnage on order
YC = Yard capability

This ratio is used to determine the model of the shipyard management policy of the fractional change/month they will make to the shipyard capability.
FCSC.K = TABHL(TBSC,OCR.K, 0, 2,.2)
TBSC = .21/.16/.08/.04/0/.04/.07/.05/.1/.1

FCSC.K = Fractional change in shipyard capability.
TBSC = Table to determine FCSC.
OCR.K = Order capability ratio.

When the order capability ratio, which is the ratio of tonnage on order and under construction, divided by the present yard capability, is greater than one (that is, there are more orders than capability), the fractional change to be made in shipyard capacity, determined by table TBSC (see figure 18) is positive. When the ratio is less than one (that is, there are fewer orders arriving at the shipyard than ships being produced), the fractional change from the table is negative.

The fractional change in shipyard capacity is then multiplied by present yard capacity to determine the amount of capability to be added.

RCSC.K = (YC.K)(FCSC.K)
RCSC = Intended amount of change to shipyard capability.
YC = Shipyard Capability
FCSC = Fractional change to shipyard capability.

1 In review, the table, TBSC, is set so that when TCO=YC there will be no additions to yard capability. As orders fall off and the ratio, OCR, becomes less than one, yard

1 See Figure 18.
capability will be reduced at the same rate at which the ratio is reduced. This is done so that there will be no excess capacity above the tonnage on order. As orders increase, and tonnage on order increases, yard capability will be increased at a slightly lower rate than the increase in the ratio. This is to give weight to the fact that shipyard management tries to keep fluctuations and layoffs to a minimum. It is assumed that these changes are changes in labor and therefore, effective almost immediately. We have decided not to encompass in this model changes in the yard physical plant which would take about five years. We cannot let the changes in labor force continue to the point that they exceed the physical plant of the shipyard. Therefore, we placed an upper limit beyond which yard capability cannot increase. This is shown in the equation for \( \text{MAXYC} \).

\[
\text{MAXYC} = 266 \quad 10^9 \text{ ton miles/month}
\]

The difference between yard capacity and maximum yard capacity is compared with the intended amount of change to shipyard capacity and the minimum becomes, ACSC, the actual addition to shipyard capacity used in the equation determining \( YC \), shipyard capability. This is formulated as follows:
CCU.K = MAXYC-YC.K
ACSC.KL = MIN(RCSC.K, CCU.K)

MAXYC = Maximum yard capacity.
YC = Shipyard capability.
ACSC = Actual addition to yard capacity.
RCSC = Intended addition to yard capacity.
CCU = Maximum intended addition to yard capacity.

Once we have changed the capacity that the shipyard can handle we must change the level of ships under construction. We do this by determining the additions to ships under construction, ASYC, which is used in the equation to determine ships under construction, SUC. To do this we must determine whether we have more yard capacity available than orders or more orders than yard capacity. The available yard capacity is the difference between yard capacity and ships under construction.

CAFNC.K = (1/TOAS)(YC.K-SUC.K)

TOAS = Time to adjust shipyard.
CAFNC = Capacity available for new construction.
SUC = Ships under construction.

The orders ready to go into production equal:

TANC.K = (1/TOAS)(TOO.K-SUC.K)

TANC = Tonnage on order ready for new construction.
TOO = Tonnage on order and under construction.
SUC = Ships under construction.
If there is available productive capability in the shipyard to handle all of the orders (TANC) then these orders become ships under construction directly. If, however, there is not enough capacity in the shipyard to handle all of the orders, only those orders which the shipyard can manage become ships under construction (CAFNC). Therefore, the addition to ships under construction is the minimum of these two capacities:

\[
\text{ASYC.KL} = \min(\text{TANC.K} - \text{CAFNC.K})
\]

ASYC.KL = Additions to shipyard construction.
CAFNC.K = Capability in the shipyards available for new construction.

The time to adjust the shipyard, TOAS, is set equal to one month. This represents the delay in using additional capability that has been implemented by the shipyard manager.

Finally, in this sector we compute a factor which affects the price an owner pays to construct a ship. First, we determine backlog which is the difference between tonnage on order and ships under construction. Then we compare the total of yard capability plus backlog with the maximum yard capacity to determine the factor which affects the price of new buildings. (See figure 178)

The appropriate equations are:
BLOG\_K = TOO\_K - SUC\_K
UTIL\_K = (1/\text{MAXYC})(\text{YC}\_K + \text{BLOG}\_K)

BLOG = Backlog.
TOO = Tonnage on order and under construction.
SUC = Ships under construction.
MAXYC = Maximum yard capacity.
YC = Yard capacity.
UTIL = Utilization of shipyard capability.

The utilization factor is then used to determine the factor used in the Market Sector to determine the price of new ship buildings.

\text{FACTOR}\_K = \text{TABHL}(\text{TBFAC},\text{UTIL}\_K,0,2,.5)
TBFAC = .95/.975/1/12/1/25

FACTOR = Factor affecting the price of ships.
TBFAC = Table to determine the above factor for the utilization of shipyards.

As orders increase some of them will go into backlog before going into construction, SUC. When maximum yard capability is reached, all additional orders will go into backlog. UTIL is the measure of the capability being used in the shipyard. If the utilization is low the shipyard managements will tend to reduce prices to bring work to the yard. When utilization is high and there is a backlog of work the shipyard management will tend to increase the price of ships and increase their profit.
This completes the formulation of the Shipyard Sector. We have developed the production rate for the Capacity Sector, and the "utilization of shipyard capacity," to be used in the Analysis Sector to determine the delivery time of the ship ordered, and in the Market Sector to develop the price of the ship ordered.
Chapter 6

THE SIMULATION MODEL

Detailed Description of The Analysis Sector

In this chapter we describe the equations which will be used to analyze the costs of the alternate methods of supplying the demand of a hypothetical oil company. Using inputs from the previously described sectors and the forecast demand for the next three and a half years for an oil company, the model develops both the total cost of each of the alternatives and the long term charter rate which the oil company will have to receive over the remaining life of the ship, if they were to charter out the ship at month 42, for the rest of the ship's life. This rate will guarantee for the company a specified return on investment after taxes.\(^1\) Graphically the analysis sector is very complicated, and is shown in figures 20A, 20B and 20C.

Specifying the Demand of a Hypothetical Company

Starting in the top middle part of figure 20A, we specify the forecast demand of an oil company.

\(^1\) In the simulations completed rates of return of 6\% and 10\% were used.
price of new ships \( \text{EQPSH.K} \) from market sector \( N \)
marginal demand of an oil company \( \text{MARLV.K} \)

\[
\text{18 month forecast of demand} \\
\text{FORLS.K}
\]

\[
\text{boxcar function stores value for 18 months} \\
\text{PRIS*1} \\
\vdots \\
\text{PRIS*18}
\]

\[
\text{.8 x 18 mo. forecast} \\
\text{ACT.K}
\]

\[
\text{actual demand that occurred} \\
\text{ACTLV.K}
\]

\[
\text{modified price} \\
\text{MOPP.K}
\]

\[
\text{monthly equiv. price} \\
\text{MODP.K}
\]

\[
\text{an index} \\
\text{ZOL.K}
\]

\[
\text{THE ANALYSIS SECTOR} \\
\text{(figure # 20A)}
\]
MARLV,K = RAMP(MARL3,0)

MARLV = Marginal level of transportation demand (demand in excess of that being transported in owned or long term chartered ships)

RAMP = Equation type which states MARLV as an initial value and increases the demand by a specified increment, MARL3, each time period.

MARL3 = Expected rate of increase in marginal demand per unit time.

For this simulation we have set the additional demand that the hypothetical oil company desires at 2x10^9 ton miles/month capacity. This is about 3/10ths of a percent of the capacity of the total world fleet. We have further specified that this additional demand will increase by 5.8% per month. This is formulated by:

MARLV = INT40
INT40 = 2
MARL3 = (MARL)(INT40)

INT40 = Initial value of the marginal demand.
MARL = The percentage increase of demand per unit time.
MARL3 = The amount of increase of demand per unit time.

Once we have introduced the specified forecast we must calculate what the level of marginal demand will be about 18 months in the future so that we may specify what tanker capacity to order for each alternative ordering time. The level is formulated by:
\[ \text{FOR18}_K = \text{MARLV}_K + \text{MARL2} \]
\[ \text{MARL2} = (18)(\text{MARL}) \]

\[ \text{FOR18} = \text{Forecasted demand 18 months from present.} \]
\[ \text{MARL2} = \text{The addition to demand expected over the next 13 months.} \]
\[ \text{MARLV} = \text{Marginal level of demand now.} \]

Since we will choose to build ships only for a percent of this need we multiply our forecast by a factor (PER). This is due to avoid large over-capacity. As an initial policy we choose to make this factor .8.

\[ \text{PER} = .8 \]
\[ \text{ACT}_K = (\text{FOR18}_K)(\text{PER}) \]

\[ \text{ACT} = \text{The actual order that would be put to the shipyard for delivery 18 months later, for the various alternatives.} \]
\[ \text{PER} = \text{Percent of total marginal demand we would build as a maximum.} \]

Since the price we pay is determined at the time we order, but payment is not made until a later time, we wish to resolve this price and store it for later use. Therefore, we define a box car function which will store the amount we will have to pay for this ship or ships for 18 months. The input equation for this box car will be:

\[ \text{PRIS}^*_1.K = (\text{ACT}_K)(\text{EQPSH}_K) \]
PRIS\* = Contracted price of new ships we wish to build to be stored for 18 months.

ACT = Capacity of new ships we wish to price.

EQPSH = Price to build new ships from shipyard sector.

Simply, the total price is equal to the total capacity times the price per capacity. We also must store the capacity that we have ordered since we will need to deduct this capacity from that which we obtain from the spot market. We do not deduct it until 18 months have passed and therefore must store it for that length of time. To do this we define another box car function which has an input equation of:

\[ \text{FOR}^* \text{L.K} = \text{ACT.K} \]

\text{FOR}^* = \text{Capacity of the new building to be stored for 18 months.}

\text{ACT} = \text{Capacity of the new building we are ordering.}

After the price of the ship has been stored for 18 months, representing the building of the ship, it must be paid for by the company. Actually, this price has been paid for over the construction of the ship, and to represent these payments as the present value at the time of the order + 18 months, we modify our stored price. We also modify the present value of this price less the present value of its depreciation tax shield for 20 years to a 20 year monthly annuity to add to the monthly operating cost of the ship for comparison with the spot rate. This
is done by;

\[
\text{MOPK} = (\text{PRIS}^{*}18.\text{K})(\text{MOD})(1+(-.432)(\text{PRIS}^{*}18.\text{K})(\text{DPRE})
\]
\[
\text{MODP} = (\text{MOPK})(\text{ECST})
\]

\text{MOD} = Modified price in $/month. This value is equal to a monthly annuity which we would have to pay to equal the present cost of the new buildings less the present value of its depreciation tax shield.

\text{MOPP} = The present value of the cost of the ship less its depreciation tax shield's present value.

\text{PRIS}^{*} = Total present cost of the new buildings in $10^{6}.

\text{MOD} = A factor to bring the cost of new buildings which have been paid for in four equal installments over the construction period to the present. It is calculated by:

\[
\text{MOD} = \sqrt[12]{1+(1+\text{RATE})^{6}+(1+\text{RATE})^{11}+1(\text{RATE})^{12}}
\]

\text{RATE} = The monthly rate of interest we are considering.

This equation compounds the quarter payments made when the order was placed, six months later and 12 months later, to the time when the ship was delivered, and adds the value of these payments to the payment made at delivery. Thus the cost of the ship is the stated cost from the shipyard plus the time value of the money paid to the shipyard when the vessel is not yet operating.

For a 6% yearly interest rate MOD = 1.065.

\text{-.432} = The tax rate of .48 multiplied by .9, which is a factor representing that 90% of the cost of a ship can be depreciated.

\text{DPRE} = The present value of $1 depreciated by the sum-of-the-years-digits method of depreciation at a specified rate of interest. The value for a 6% rate of interest is .677.

\text{ECST} = The conversion factor which equates the given present value to a 20 year monthly annuity at the specified rate. For 6% this factor is .007164. Since the stored price, \text{PRIS}^{*}, is in 10^{6} dollars, \text{ECST} = 7164.

The first equation states that the actual cost of the ship ordered is equal to the price stated by the shipyard
multiplied by a factor which adds the time value of money
paid to the shipyard before the vessel is launched less the
present value of the depreciation tax shield. The second
equation relates this value to an equal monthly annuity
for 20 years.

This developed annuity for the cost of the ship
will be used to determine the total cost of each alternative.
This will be described later in the chapter.

The operating cost to be used for each new building
is determined from a table and is dependent on how large the
new building will be. The formulation of this table is:

\[
\begin{align*}
\text{OPX01.K} & = \text{TABHL(TOPEX, VOL.K, 1, 3, .25)} \\
\text{TOPEX} & = 83.4/80.4/77.9/75.7/73.9/72.4/71.9/70.4/69.9 \\
\text{OPX} & = \text{Monthly operating expense of a vessel, including} \\
\qquad \text{fuel costs, in $10^6 \text{ ton miles/month capacity.}} \\
\text{TOPEX} & = \text{Table to determine operating cost from size of} \\
\qquad \text{new building.} \\
V & = \text{Capacity of delivered new vessel in } 10^9 \text{ ton miles per month.}
\end{align*}
\]

Once the operating cost is known it is multiplied
by capacity to obtain the dollar amount of operating cost
per month.

\[
\begin{align*}
\text{OP501.K} & = (\text{OPX01.K})(\text{VOL.K})(1000) \\
\text{OPE} & = \text{Operating cost in $/month for the vessel specified.} \\
1000 & = \text{Conversion factor to $/month from 1000 $/month.}
\end{align*}
\]

1

Before we can compare alternatives we need an actual demand, including a random element, to determine the total cost for the transportation acquired on the spot market. We achieve this by:

\[
\text{ACTLV}_K = \text{MARLV}_K + \text{VAR2}_K \\
\text{VAR2}_K = (R03)\text{NORMRN}(0, R02) \\
R02 = .4
\]

\text{ACTLV} = \text{The actual demand required.}  \\
\text{VAR2} = \text{A random number generated from a normal distribution with 0 mean and R02 standard deviation.}  \\
\text{R02} = \text{The standard deviation of the historical variance of oil company forecasts, taken initially as 40\% of demand forecasted.}

**Description of the Analysis for Each Alternative**

For each alternative (the 24 alternatives are: alternative #1 is buying a ship in month 0 for delivery in month 18, alternative #2 is buying a ship in month 1 for delivery in month 19, etc., until alternative 24, which is to order a ship in month 24 for delivery in month 42.), there is a separate program which gives the equivalent monthly cost for using that alternative. After the program has been run the alternative with the least equivalent monthly cost may be picked. In our exposition of the formulation all equations will be written for alternative #1. All alternatives are the same except alternative #25 which is the alternative of supplying all needs from the spot market.
In this section we will explain the formulation of the above analysis. Before doing so let us note the following results of the final section of this chapter.

\[
\begin{align*}
V_{01.K} &= F_{OR*18.K} \\
S_{IP01.K} &= M_{ODP.K}
\end{align*}
\]

\*\text{FOR} = \text{The capacity of a new building ordered about 18 months previously.}
\text{V} = \text{Capacity of the delivered new building for the respective alternative.}
\text{MODP} = \text{Modified price of a new building on order.}
\text{SIP} = \text{Modified price of the delivered new vessel.}

These equalities simply state that the capacity and cost of the delivered ship equal that of the ship when it was ordered.

Starting in the upper center of figure 20B we notice that the additional demand of the hypothetical oil company and the price in the spot market are combined to obtain the cost of transportation provided through the spot market by the following equation:

\[
\begin{align*}
M_{QPCH.K} &= (E_{QPCH.K})(.52)(403,000) \\
A_{MOL.K} &= (M_{QPCH.K})(\text{ACTLV.K}-V_{01.K})
\end{align*}
\]

\text{EQPCH} = \text{The spot charter price index in \$/1000 ton miles.}
\text{transported.}
\text{MQPCH} = \text{The spot rate index modified to show the cash flow which a company pays.}
\text{.52} = 1 - \text{tax rate}
\text{403,000=a conversion factor. Since the demand is specified in units of 10^7 ton miles capacity needed per month, that we have assumed that tankers operate with an efficiency of .403, and that the spot rate is specified in \$/10^3 ton-miles of oil transported, we must}
multiply the spot rate by this factor to obtain it in $/10^9$ ton-miles of capacity needed.

\[ AC = \text{Monthly cash flow due to dealings on the spot market for in charters.} \]

\[ ACTLV = \text{Total capacity needed per month.} \]

\[ V = \text{The capacity of the new building delivered.} \]

Simply the cash flow in any month spent in the spot market is equal to the demand for capacity less that supplied by owned ships, multiplied by the price of spot charters.

(Before the new ship is delivered, $V_{01}$ will be zero and all requirements will come from the spot market.)

If after the vessel is delivered the demand drops and the new capacity is not needed we will assume that the vessel will be placed on the spot market to obtain revenue.

The revenue from the spot market is not certain since at any rate only a given percentage of the vessels afloat are operating, and some are underemployed. To handle this situation we will use the following equations:

\[ AC_{01,K} = \text{CLIP}(AM_{01,K},AN_{01,K},AL_{01,K},K,0) \]

\[ AC = \text{Monthly cash flow due to total dealings in the spot market.} \]

\[ AM = \text{Cash flow due to in charter dealings.} \]

\[ AN = \text{Cash flow due to out charter dealings.} \]

\[ AL = \text{A variable used to determine whether during the period the company had in or out charters. This variable is defined by:} \]

\[ AL_{01,K} = ACTLV_{K} - V_{01,K} \]

\[ ACTLV = \text{The total capacity needed per period.} \]

\[ V = \text{The capacity per period of the new ship.} \]
This equation tells us whether the demand is greater than that which can be supplied by our owned ship or not.

The above says that the model will use the variable, AM, if the total capacity needed is greater than can be supplied by owned vessels, and that the model will use variable AN, if the total capacity is less than can be supplied by owned vessels. We have already specified the variable AM, which handles in chartering, so let us now define the variable AN, which handles out chartering. This is accomplished by the following equation:

\[ AN01.K = (MQPCH.K)(UNPER.K)(AL01.K) \]

\( AL \) = the total amount of out chartering to be done.
\( MQPCH \) = the cash flow corresponding to the spot rate at which the out chartering will be done.
\( UNPER \) = the probability that we will be able to out charter.

This equation says that the cash flow to the company will be equal to the amount of out chartering we do, multiplied by the probability that we will be able to obtain a charter, multiplied by the rate after taxes at which charters are being negotiated in the market.

The probability of gaining an out charter is determined from a table based on the supply demand ratio developed in chapter III. The necessary equations are:
UNPER.K = TABHL(TBDEM, SDR.K, .8, .97, .1)
         .71/.72/.73/.74/.75/.76/.77/.78

UNPER = The probability of obtaining an out charter.
TBDEM = The table to determine the above probability from
       the supply-demand ratio.
SDR = The supply-demand ratio.

To obtain the total monthly cost for transporting
the specified amount of oil, the expense or revenue from
dealings in the spot market must be totalled with both the
monthly capital cost and operating cost of the new ship when
it is delivered. This is done by:


CC = Total present monthly expense.
AC = The costs from the spot market when used.
SIP = The capital cost of the new ship.
RTI = A factor to change the value of the cost from the
      last period to the next period. It is equal to 1 +
      the specified interest rate.
OPE = The operating expense from operating the ship that
      was delivered.

At the end of the calculations we intend to give
the terminal value of each alternative. To do this we must
add, each period, to the total cost accumulated to date, the
capital charge to compound it another period plus the expenses
incurred during the present period. This is done by:

1

This table is based on unpublished research by Z. S.
Zannetos, Professor, Sloan School of Management, Massachusetts
Institute of Technology, May 1967.
C\text{ST}.K = \text{CST}.J + (\text{DT})(\text{COT01}.J + \text{CC01}.J)
\text{COT01}.K = (\text{CST1}.K)(\text{RATE})(\text{DT})
\text{CST01} = \text{Present value of the total cost of this alternative up to the present}
\text{COT01} = \text{The additional cost incurred by moving the total cost from the last period up to the present.}
\text{CC01} = \text{The cost of supplying the present needs with regard to transportation.}

The first equation says that the total accumulated cost at the end of period K is equal to the total accumulated at the end of the previous period plus the interest charge on the total for one period plus the cost accumulated in the previous period. The second equation calculates the costs of the previous period including the interest charge for the period after which the cost is incurred.

Once the simulation is complete and the alternatives have been calculated through the desired time interval, we will have stored, under the label \text{CST}, the total cost for the given alternative, incurred during the specified time. We wish to change this to an equivalent monthly cost. To accomplish this we use the following:

\text{EMC01}.K = (\text{CST01}.K)(\text{RATE})/\text{DCB}
\text{EMC} = \text{The equivalent monthly cost}
\text{DCB} = \text{A constant equal to } (1.005)^t - 1, \text{ which equates a payment at the end of a specified time to a monthly annuity at 6% per year, when it is divided by the rate.}
The equivalent monthly cost is one way to compare alternatives. Another way, introduced in chapter II, is to find at the end of a given time what revenue must be earned by the ship for the rest of its life in order to pay operating and capital costs. This revenue is determined on the assumption that we have received the rates simulated for the first periods of operation of the ship. Another way to look at this is to realize that if we didn't have the ship we would have to spend an amount equal to the spot rate to acquire needed capacity. The first equation needed is:

\[ FFO1.K = (F01)(CST25.K-CST01.K) \]

\[ FFF = \text{The reduction in total dollar costs for owning the new ship rather than using the spot market.} \]
\[ CST01 = \text{Three and a half year terminal cost of using alternative #1.} \]
\[ CST25 = \text{Three and a half year terminal cost of obtaining all transportation for spot market.} \]
\[ F01 = \text{A factor to spread this value over the remaining life of the ship as an annuity.} \]

This equation spreads the dollars we gained over owning the vessel rather than chartering to an annuity for the remaining life of the vessel. The second and third equations needed are:

\[ X01.K = (V01.K)(403000)(.52) \]

\[ LTC = \text{Long term charter rate needed to earn a 6% return.} \]
\[ OPE = \text{Operating costs of the vessel.} \]
\[ S1P = \text{Capital cost of the ship.} \]
\[ V01 = \text{Capacity of delivered ship} \]
403,000 = Conversion factor\(^1\)
.52 = 1 - tax rate

Here we determine the long term charter rate we would have to better over the remaining life of the ship if we are to earn a 6% return after taxes. It is the sum of the monthly expenses due to capital cost and operating cost less that annuity just calculated, divided by the amount of oil that can be transported by this ship.

These two measures, LTC, the long term charter equivalent, and EMC, the equivalent monthly cost, give us the means to compare the alternatives considered.

**Description of the Formulation of the Timing of Delivery for New Ships**

In this sector (see Figure 20c) we will formulate how the model adjusts for different delivery contracts, and how the stored values of price and capacity are delivered at the appropriate time. Again our exposition will show all formulae for one alternative, in this case Alternative #10.

For each alternative we set up two indices to keep track of the months as they expire.

\[ Z10.K = Z10.J + (DT)(-1+0) \]

**Z10** = To keep track of the time when ship for alternative 10 is ordered.

\(^1\) For full explanation see page 87.
THE ANALYSIS SECTOR

(price 20C)
R10 = Index to keep track of the time when the ship for alternative 10 is delivered.
DEL10 = The additional delivery time needed beyond 18 months, if shipyards are over-loaded.

Both indices are set at 28 months for alternative 10. This is the minimum number of months before the new building for alternative 10 can be delivered. For other alternatives this will be different.

Once the index Z10 equals 18, we check the utility factor of the shipyards to determine if any additional delay beyond 18 months will be encountered before we can take delivery on the ship. The delay is determined by:

\[ \text{DEY.K} = \text{TABH}(\text{TDEY}, \text{UTIL.K}, 0, 2, 5) \]
\[ \text{TDEY*} = 0/0/0/3/6 \]

DEY = The additional delay in months.
TDEY = Table to determine this delay for the utility in the shipyards.
UTIL = The utility of shipyard capacity, developed in chapter V.

We add this to the index R10 at the correct time (when Z10 = 18) by:

\[ \text{DDD10.K} = \text{CLIP}(0, \text{DEY.K}, Z10.K, 18, 1) \]

DELL0 = The additional delay for alternative #10 to be added to the index R10.

The above equations together perform the function of allowing DELL0.K to be zero except when Z10 = 18. When Z10 = 18, DELL0 = the additional delay quoted by shipyards at the time the order is made.
We use the Z10 index until it equals zero to store the values for the capacity, FOR*18, and the price MODP, of the new building until the second index R10 equals zero. Z10 equals zero at the month we expected to take delivery on the new building if the delivery time was 18 months. The R10 index reaches zero when actual delivery is made. We store the price by:

\[
\begin{align*}
MA10,K &= \text{CLIP}(0, \text{MODP,K,Z10,K},.2) \\
MB10,K &= \text{CLIP}(MA10,K,0,Z10,K,.1) \\
MC10,K &= MC10,J+MB10,J \\
\end{align*}
\]

MODP \rightarrow MC10 = The modified price of the new building.

The above equations store the modified price for the time period starting when index Z10 = 0 and ending when the index R10 = 0. When the index R10 = 0 we move the price from its storage in MC10 to the monthly cost of the representative alternative, SIP10. We do this by:

\[
\begin{align*}
MM10,K &= \text{CLIP}(0, \text{MC10,K,R10,K},.1) \\
SHP10,K &= \text{CLIP}(MM10,K,0,R10,K,0) \\
SIP10,K &= SIP10,J+SHP10,J \\
\end{align*}
\]

MC10 \rightarrow SIP10 = The modified cost of the new ship built under the respective alternative.

Similarly, another set of equations stores the capacity of the new ship, FOR*18, until it becomes delivered capacity, V10.K. These equations are:
LA10,K = CLIP(0,FOR*18,K,Z10,K,12)
LB10,K = CLIP(LA10,K,0,Z10,K,11)
LC10,K = LC10,J+LB10,J
LL10,K = CLIP(0,LC10,K,R10,K,11)
AV10,K = CLIP(LL10,K,0,R10,K,11)
V10,K = V10,J+AV10,J

FOR*18 → V10 = The capacity of the new building for the respective alternative.

All of these equations simply keep track of when to add capital costs and operating costs to the total cost; and when to subtract the capacity of the newly delivered ship from that obtained from the spot charter market. Having completed the formulation of the analysis sector, we may now simulate the model and compare the costs of ordering a ship in any of the alternative months over the next two years.

In the remaining chapters we will describe the results of the simulation runs with regard to behavior and costs, describe the effects of changing key relationships, and indicate areas for further study.
Chapter VII

EXPERIMENTATION

Introduction

We will now test the model for sensitiveness to varying the specifications of two key relationships and six parameters. From these tests we wish to determine whether these relationships and parameters are critical to the analysis by which we recommend that one method rather than another be used to transport oil. If a relationship is supported by the tests as being critical it will be recommended that further research be completed to more closely specify the critical values. In this chapter we will describe these experiments and report the results obtained.

It is recommended that in the future this model be used with consistent data for one point in time to predict future spot rates, and then, compare the prediction with the actual occurrence to determine the accuracy of the model. At this stage in the development of the model such a comparison would not be meaningful. The model is very sensitive to the relationships incorporated in it and to the input data prescribed. Because of the dearth of available data, some of the relationships in the model are only mathematical statements of verbal behavioral descriptions,
and some of the input data are only reasonable estimates of the quantities used.

This model is useful, nevertheless, in that it incorporates a market concept of evaluating oil tankships. By experimenting with the model we may find what relationships and what parameters are critical. In the present effort we have designed a group of experiments to do just that.

Specifications of the Different Models

There are two policies which are extremely important to the model. The first is the relationship between the spot rate and the percent utilization of the present supply of tankers. The second is the relationship between the spot rate and the policy index which determines orders for new ships. We have tested nine models incorporating all combinations for three specifications for each of the above relationships. The testing of each of these models was done for different: (a) growth rates of world oil demand, (b) percentages of seasonal demand, (c) percentages of randomness in world demand, (d) percentages of randomness in demand of the oil company for whom we are doing the analysis, and (e) interest rates.

The three specifications for the relationship between the spot rate index and the percent utilization of
available tankers are shown in figure 21. The first curve, marked 1, is the relationship explained in the detailed description of the model. The other two curves, numbers 2 and 3, were derived by multiplying the points of curve 1 by .774 and .564 respectively. It is believed that the shape of the curve is correct since it is based on a regression line put through a large amount of data. This regression was done on data from the period between 1948 and 1958 when the marginal vessel in the spot market was a T-2 with high operating costs when compared with the operating cost of the marginal vessel in the market today. Therefore, the costs determined by curve 1 may be too high for a given utilization of the fleet. The marginal vessel today is about 40,000 DWT, however, in the future it is conceivable that the marginal vessel may become one with a carrying capacity of 100,000 DWT. A 100,000 DWT vessel at 16 knots can transport approximately \( 4.6 \times 10^9 \) ton miles per month. Its operating costs are about $90,000 per month and the discounted capital cost of the ship at 8% per year interest rate is about $71,000 per month. This means that the vessel must have a long term charter of about $.35/1000 ton miles of oil transported to earn its keep.

If we assume that a 100,000 DWT ship is the marginal vessel in the market and that it will be tied up if it can't get a charter to cover operating and capital costs, then we
THREE SPOT RATE DETERMINING RELATIONSHIPS

(Figure #21)

SPOT RATE INDEX 2.50

$/10^3$ BBL.
MILES TRANSPORTED

RELATIONSHIP 1 2 3

SUPPLY-DEMAND RATIO, REPRESENTING THE UTILIZATION OF TANKERS
can use $.35/1000 ton miles transported as the lowest charter rate that should occur in the market. Thus, we derived curve 3 by multiplying curve 1 by a factor which brings the minimum rate that can be specified to $.35/1000 ton-miles transported. The second relationship was placed arbitrarily between the other two.

Admittedly the above analysis is crude; however, it is felt that we have surrounded the area where the true curve lies. By testing with these curves we will be able to analyze how our decision will be affected by a lowering of the cost determined by this relationship, and therefore, our purpose is satisfied.

In the testing procedure relationship 1 will be used in model numbers 1, 4 & 7; 2 will be used in models 2, 5 & 8, and 3 in models 3, 6 & 9.

We have also chosen three curves (see figure 22), to represent possible relationships between the spot rate and orders to shipyards for new ships. The data compiled for this relationship show much scatter and, therefore, we have chosen three widely varying curves to use in our models. An analysis of the data shows that orders do go up with the spot rate, and that they only diminish after the spot rate declines. By ignoring certain points of the data, and doing this differently three times, we can draw through

---

1 Z. S. Zannetos, op. cit., pp. 76-82.
THREE ORDER POLICY
DETERMINING RELATIONSHIPS

(Figure 22)

VALUE FOR TABLE 'BARN' WHICH AFFECTS ORDER RATE OF NEW SHIPS

RELATIONSHIP

SPOT RATE INDEX FOR THREE SPOT RATE DETERMINING RELATIONSHIPS - $1/10^3$ t/m
the data points a smooth curve similar to the curves in figure 22. Having specified these curves we can test the model to determine what effect such world ordering policies have on the alternative methods by means of which an oil company can transport its oil.

Curve 1 is used in models 1, 2 & 3; curve 2 is used in models 4, 5 & 6; and curve 3 is used in models 7, 8 & 9.

Testing the Model

Defining each of the nine models as one of the combinations of the above relationships placed in the total model, we chose to test each of these models with varying parameters. Table 7-1 is a summary of the relationships used in each of the models.

Test 1 of each of the models has the following characteristics:

a) World-wide growth rate of demand for oil = 6.3%/year
b) Seasonal fluctuation in demand for oil = 10%
c) Random fluctuation of world-wide demand = 5%
d) Random fluctuation of oil company's demand = 20%
e) Percent of expected demand ordered = 80%
f) Interest rate = 6%

The results of the first test done on all nine models is shown in figure 23. The best alternative for each of the models is marked by a small triangle under each curve, and are summarized in table 7-2. Figure 23 shows the
### TABLE # 7 - 1
**SUMMARY OF DIFFERENT MODELS**

<table>
<thead>
<tr>
<th>relationship by which spot rate affects order policy</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(TBWQ)</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>relationship between spot rate and utilization of supply of tankers (TBEQP)</td>
<td>2</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

1. Refer to figure # 21.
2. Refer to figure # 22.

### TABLE # 7 - 2
**SUMMARY OF RESULTS, TEST 1**

<table>
<thead>
<tr>
<th>spot rate relationship</th>
<th>model number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

| best alternative      |              | 4 | 4 | 2 | 4 | 15 | 2 | 24 | 24 | 4 |
|                       |              |   |   |   |   |    |   |    |    |   |
| equivalent monthly cost|             | 790 | 702 | 1103 | 651 | 581 | 887 | 488 | 432 | 688 |
|                       |              |   |   |   |   |    |   |    |    |   |
| break even long term charter |    | .51 | .52 | .42 | .55 | .54 | .48 | .55 | .55 | .53 |
|                       |              |   |   |   |   |    |   |    |    |   |
| order policy relationship |          | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |


equivalent monthly cost for each alternative month of ordering a ship. The results show differing costs for each of the models for all of the alternatives as we had expected. They also show that the best alternative changes with each of the models.

Noticing how the best alternative changes, gives us an indication as to the importance of knowing which is the behavior in the world. For order policy 3, given in models 3, 6 & 9, the best alternative is moved forward in time from the other models. This happens because such a world-wide policy of ordering will cause the spot rates in the market to have a higher average over the course of time. We can also notice that as the spot rates determined by the supply demand relationship become lower that the best alternative tends to be moved to a later point in time. This effect occurs for order policy 1 between spot rate relationships 2 and 3; for order policy 2, between spot rate relationships 1 and 2, and between spot rate relationships 2 and 3; for order policy 3 this only occurs to a small degree between spot rate relationships 2 and 3. The results indicate that different world ordering policies affect the level and pattern of spot rates and therefore which alternative method used to transport oil is the best. If the oil companies united to adopt an order policy of the magnitude and shape of our policy 2 rather than that of 1 or 3, they could probably keep
costs on the spot market low, and, therefore, operate more beneficially to themselves.

The results of model 5 substantiate what we regard to be one of the major critical relationships this study attempts to establish. It is shown that the time when an oil company orders its ships can influence extensively the price it pays for its transportation needs. In figure 24 the results of model 5 in test 1 have been replotted on a larger scale for emphasis. Also the equivalent monthly cost that would have been incurred had the company derived all of its needs from the spot market has been superimposed across the plot of the costs of each alternative. We observe that by ordering the ship in month 5 or 15 the oil company could do much better than the market. If they ordered in months 1, 8 or 20 they would have done poorly.

The savings which could have been derived if the model was the real world, for the demand specified, would be as follows:

Between the best alternative and procuring all needs from the spot market, there is a savings of.......................$5,680/mo.

Between the best alternative and the worst there is a savings of........................................$9,640/mo.

In test 2 of each model we changed the growth rate of world-wide demand from 6.3%/year to 10%/year. The results from this test are summarized in table 7-3. From this table
RESULTS, MODEL 5 - TEST 1

(FIGURE # 24)

EQUIVALENT MONTHLY COST

$ \times 10^3$

ALTERNATIVE NUMBER = MONTH IN WHICH SHIP WAS ORDERED

COSTS IF ALL NEEDS PRODUCED THROUGH SPOT MARKET
### Table # 7 - 3
COMPARISON OF RESULTS, TESTS 1 & 2

<table>
<thead>
<tr>
<th>model</th>
<th>test 1</th>
<th>test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>growth rate 6% /year</td>
<td>growth rate 10% /year</td>
</tr>
<tr>
<td></td>
<td>best alt.</td>
<td>EMC $\text{(10)}^3$</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>790</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>702</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1103</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>651</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>581</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>887</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>488</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>432</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>688</td>
</tr>
</tbody>
</table>

### Table # 7 - 4
COMPARISON OF RESULTS, TESTS 1 & 3

<table>
<thead>
<tr>
<th>model</th>
<th>test 1</th>
<th>test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>seasonal variation 10%</td>
<td>seasonal variation 20%</td>
</tr>
<tr>
<td></td>
<td>best alt.</td>
<td>EMC $\text{(10)}^3$</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>790</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>702</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1103</td>
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<tr>
<td>4</td>
<td>4</td>
<td>651</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>581</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>887</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>521</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>432</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>688</td>
</tr>
</tbody>
</table>
we may observe that there is very little effect on each of the models. Only in two cases was the best alternative moved up, and in those cases only by two months.

In test 3 we changed the percent of demand that is seasonal from 10% to 20%. In this test we also observe very little change across the models. The results are summarized in table 7-4. From the results of these two tests we deduce that neither of these factors will play a significant role in our decision problem, and recommend that as long as reasonable figures are used that no great effort be spent to determine the exact value of these parameters. For the test of model 9 with the increased percentage of seasonal fluctuation, we have plotted the results for each alternative and they are shown in figure 25. We have plotted this to show that in this test and this model there are alternatives by which the oil company can do better or worse than by using the spot market for all of its needs.

In tests 4 and 5 we varied the world demand randomness. In test 1 the randomness was 5% of the total demand. In test 4 we specified no random demand, and in test 5 randomness equal to 10% of demand. The results are shown in table 7-5. In this case we also notice very little difference in the best alternative for each model. It seems that the set of random numbers under which the model was tested does not affect the demand enough to overshadow other effects.
### TABLE # 7 - 5

**Comparison of Results, Tests 1,4 & 5**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>TEST 4</th>
<th></th>
<th></th>
<th>TEST 1</th>
<th></th>
<th></th>
<th>TEST 5</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO RANDOMNESS IN WORLD DEMAND</td>
<td>5% RANDOMNESS IN WORLD DEMAND</td>
<td></td>
<td>10% RANDOMNESS IN WORLD DEMAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>best</td>
<td>alt.</td>
<td>EMC</td>
<td>$10^3$</td>
<td>LTC</td>
<td>$10^3$</td>
<td>alt.</td>
<td>EMC</td>
<td>$10^3$</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>786</td>
<td>.51</td>
<td>4</td>
<td>790</td>
<td>.51</td>
<td>4</td>
<td>812</td>
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<tr>
<td>2</td>
<td>3</td>
<td>703</td>
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<td>712</td>
<td>.53</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1088</td>
<td>.42</td>
<td>2</td>
<td>1103</td>
<td>.42</td>
<td>2</td>
<td>1142</td>
<td>.41</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>650</td>
<td>.54</td>
<td>4</td>
<td>651</td>
<td>.55</td>
<td>4</td>
<td>665</td>
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</tr>
<tr>
<td>5</td>
<td>3/15</td>
<td>589</td>
<td>.53/.54</td>
<td>15</td>
<td>581</td>
<td>.54</td>
<td>15</td>
<td>585</td>
<td>.54</td>
</tr>
<tr>
<td>6</td>
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<td>.47</td>
<td>2</td>
<td>887</td>
<td>.48</td>
<td>2</td>
<td>916</td>
<td>.47</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>500</td>
<td>.55</td>
<td>24</td>
<td>488</td>
<td>.55</td>
<td>24</td>
<td>492</td>
<td>.55</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>450</td>
<td>.55</td>
<td>24</td>
<td>432</td>
<td>.55</td>
<td>24</td>
<td>427</td>
<td>.55</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>688</td>
<td>.52</td>
<td>4</td>
<td>688</td>
<td>.53</td>
<td>4</td>
<td>705</td>
<td>.53</td>
</tr>
</tbody>
</table>
I, therefore, recommend that before the model be tested further under different orders of magnitude of random numbers or different sets of random numbers, that other work, such as that described in chapter VIII, be done.

In tests 6 and 7 we varied the randomness of the demand of the hypothetical oil company. In test 6 the randomness was specified at zero, and in test 7 at 40% of demand. Test number 1 had a randomness of 20%. The results of these tests, shown in table 7-6, are similar to the tests made by varying the randomness of world-wide demand. Therefore, it is again recommended that other work be done before resuming tests on randomness.

In test 8 the percent of forecast demand that was ordered by the oil company was increased to 90% from the 80% level used in the other tests. It was felt that such a test would make a difference because when the demand fluctuates downward the company must put its ship on the spot market and only obtain an uncertain amount of revenue. This amount will not equal the amount of revenue allotted to the ship because the oil company did not have to use the market when demand is high. This is true since the oil company has to pay the going rate 100% of the time when it has to use the market, but will only have a probability of obtaining revenue when they try to out-charter since they will be competing with other ships for the available charters. The
<table>
<thead>
<tr>
<th>MODEL</th>
<th>test 6</th>
<th>test 1</th>
<th>test 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO RANDOMNESS IN OIL COMPANY'S DEMAND</td>
<td>20% RANDONNESS IN OIL COMPANY'S DEMAND</td>
<td>40% RANDOMNESS IN OIL COMPANY'S DEMAND</td>
</tr>
<tr>
<td></td>
<td>best</td>
<td>EMC</td>
<td>LTC</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>785</td>
<td>.51</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>700</td>
<td>.52</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1096</td>
<td>.42</td>
</tr>
<tr>
<td>4</td>
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<td>487</td>
<td>.55</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>431</td>
<td>.55</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>686</td>
<td>.53</td>
</tr>
</tbody>
</table>
results were disappointing, in that they showed very little affect on the decision as to which is the best alternative. These results are shown in table 7-7. They indicate that oil companies can obtain a large percentage of their demand when they order a new ship without changing the best time to order the ship. This does not mean that the percentage of demand ordered will not affect costs. Looking at table 7-7 we notice that for the same pattern of spot rates in each model, the costs decrease in six instances and increase in three. From this we see that this parameter does affect costs. Since this test was done at 6% interest rate and at this cost of capital there is probably a large bias toward buying a ship rather than using spot charters, we will run this test again at a higher interest rate and analyze the results.

Before describing the above test let us ascertain the effect of different interest rates on our decision policy. In test 9 the interest rate was raised from 6% to 10% per year. The results of this test are shown in table 7-8. We can notice that using a higher interest rate, or cost of capital to the oil company, pushes the best alternative month to order ships back in time. For models 2, 4, 5 and 9, this is true. Since models 7 and 9 were already pushed back to their latest alternative, there is no change in these models. Only in models 1, 3 and 6 the best alternative does not
TABLE # 7 - 7

COMPARISON OF RESULTS, TESTS 1 & 8

<table>
<thead>
<tr>
<th>model</th>
<th>test 1</th>
<th>test 2</th>
<th>test 3</th>
<th>test 4</th>
<th>test 5</th>
<th>test 6</th>
<th>test 7</th>
<th>test 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>best alt.</td>
<td>EMC $(10)^3$</td>
<td>LTC $/10^3tm$</td>
<td>best alt.</td>
<td>EMC $(10)^3$</td>
<td>LTC $/10^3tm$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>790</td>
<td>.51</td>
<td>3</td>
<td>778</td>
<td>.51</td>
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<td>702</td>
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<td>4</td>
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</tr>
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</tr>
<tr>
<td>6</td>
<td>2</td>
<td>887</td>
<td>.48</td>
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<td>681</td>
<td>.53</td>
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<td></td>
</tr>
<tr>
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<td>Test 1</td>
<td></td>
<td></td>
<td></td>
<td>Test 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------:</td>
<td>------</td>
<td>------</td>
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<td>-------:</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>interest rate 6%/yr</td>
<td>EMC</td>
<td>LTC</td>
<td>interest rate 10%/yr</td>
<td>EMC</td>
<td>LTC</td>
<td>interest rate 10%/yr</td>
<td>EMC</td>
</tr>
<tr>
<td>best</td>
<td>alt.</td>
<td>$(10)^3$</td>
<td>/$10^3 t.m$</td>
<td>best</td>
<td>alt.</td>
<td>$(10)^3$</td>
<td>/$10^3 t.m$</td>
<td>best</td>
</tr>
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<td>14</td>
<td>721</td>
<td>.64</td>
<td>14</td>
<td>722</td>
</tr>
</tbody>
</table>

* Interest rate = 60%; 40% randomness in oil company demand; 95% of forecast ordered.
change. In model 1 this can be explained by the high level of spot rates combined with order policy 1. In models 3 and 6, by the order policy 3 which says that most companies will delay ordering vessels until there is a high spot rate. This best shows that the cost of capital clearly affects our decision, and tells us that a meaningful analysis should include a detailed study of the cost of capital to an oil company.

To further illustrate the effect that interest rate has we have plotted in figure 26 for model 4, the results of test 1 with a 6% interest rate and test 9 with a 10% interest rate. The least cost alternative for a 10% interest rate is the one which has us order the ship at month 15. The least cost alternative using a 6% interest rate has us order the ship in month 4. Since the peaks and troughs of the curve occur at similar places on both curves we can attribute the changing best alternative to the relationship between the cost of the alternatives and purchasing all of our needs from the spot market. With a 6% interest rate the relative cost of the spot market is so high that each month we delay ordering we mount up costs at such a rate that we are not able to take advantage of the dip in equivalent costs occurring in month 15. Since the costs incurred from buying a ship or procuring needs from the spot market are closer to being equivalent with a 10% interest rate than with
a 6% interest rate, we may delay purchasing a ship until the 15th month without having spent a relatively large fortune on the spot market.

In this figure we also show a plot of the equivalent monthly cost versus the various alternatives for model 4 under test 10. In this test we used an interest rate of 10%, we increased the percentage of the estimated demand that the oil company orders to 95% and made the test with 40% of the oil company's demand random. The results for all models is shown in table 7-8. Again we see that a change in the percentages of demand ordered does not change the best alternative, but it does change the cost. With a higher interest rate the cost is increased in the majority of cases. For model 4, we have also shown this phenomenon in figure 26. We see that for a 10% interest rate we increase our costs for all internatives by ordering 95% instead of 80% of demand. We conclude from this that after the cost of capital is determined additional tests should be made for a series of percentages of demand ordered. It is felt that a series of curves similar to those shown in figure 26 will be the result, and the alternative which minimizes cost for the minimum curve may be chosen.

There are three cases where the cost actually decreased by ordering a large percentage of forecast demand at the minimum alternative. By plotting the test for model 6
RESULTS
MODEL 4
TESTS 1, 9, 10

(Figure #26)

EQUIVALENT MONTHLY COST
FOR TESTS 9 & 10

$ \times 10^3$

NOTE: DASHED LINES ARE FOR
MONTHLY TEST 10.
MEAN FROM AFT MARKET.
EXPECTATIVE MODELS

ALTERNATIVE NUMBER
we see that the cost is lower for alternatives 1 through 18, and higher for alternatives 19 through 24. Since the cost is relatively high in the spot market as compared with owning ships, and even if a company put a surplus ship on the market to gain revenue it will bring in more than enough money to offset its costs even though the vessel will be hired only a portion of the time, the phenomena is explained.

**Summary of Results**

In brief our findings indicate the following:

1) that our model is sensitive to the relationship which determines the level of spot rates, the relationship which determines order policy for new ships, and to the interest rate at which money is discounted;

2) that the model is relatively insensitive to the world-wide growth of oil demand, the percent of world demand that is seasonal and the percent of world demand that is random;

3) that changing the percent of demand that is random for the hypothetical oil company, and changing the percent of forecast demand which the oil company orders have little effect on which alternative month is best to order a ship, but does have an effect on the total cost of the best alternative.
Chapter VIII

CLOSING ANALYSIS

Introduction

I have separated the recommendations for further study into two groupings. The groupings give a priority to the recommendations in such a manner that the proof of the forecasting ability of the model may be determined before refinements to the technique are perfected. These recommendations, as well as some general observations, are included in this chapter.

Recommendations for Further Study, Anterior

It is my suggestion that the following be completed:

1) That further data relating the spot rate to the utilization of the supply of tankers be researched, and further analysis be completed in order to determine the level of spot rates prevalent for a given utilization in the market today.

2) That a similar study be achieved with regard to the relationship which determines the order policy for new ships from the spot rate. This study should be done to determine the shape as well as the level of the relationship.

3) That a detailed research project be concluded which will provide consistent data for all the input variables.
to the model for one point in time, and also provide the information for the next 42 months necessary to test the forecasting ability of the model. This will be a difficult and tedious task.

4) That the model be tested with this consistent set of data, and its ability to forecast determined.

5) That the model be tested at various interest rates from 6 to 10 per cent at ½% intervals. This set of test results will enable the model to be analyzed for different costs of capital specified, without having to research what the cost of capital to a specific company is.

Recommendations for Further Study, Posterior

The previous recommendations have been given in the order which it is felt the studies should be undertaken. The following suggestions, in contrast, do not depend on each other. They are intended to outline a number of studies which are broad and far-reaching but which also have bearing on this model.

These suggestions are:

1) The research on the cost of capital to an oil company be undertaken. This research should include determination of the level of this cost, definition of the riskiness of an investment and determination of how risky the investment in a ship is, assessment of how the cost of capital
varies with risk, and finally derivation of the relationship between the cost of capital and the amount of debt carried by the company.

7) That a more detailed design of the shipyard sector be implemented in the model. This new design is envisioned to include a better representation of how the price of ships changes with the order rate for tankers, and how it is affected by the market for new building of other types of ships.

8) That a study be done which would relate the spot rate to the marginal vessel in the market, and that this and a forecast of the marginal vessel in the market be incorporated in the model.

9) That the effect an oil company has on the spot market, when it decides to own or spot charter a large portion of its required tonnage, be studied, modeled and introduced in the present model. The present model assumes that the demand for transportation by any individual oil company making the decision will not affect the spot market, whether the decision is to procure the tonnage on the spot market or to buy new ships. This would not be so if a large company such as the Shell Oil Company or the Standard Oil Company of New Jersey decided to shift from owning only 50% of their transportation needs to 80%.
There are many more recommendations which could be made to further the sophistication of the model. Before these undetermined studies are done, and probably, before some of the mentioned studies are done, some thought must be given to the implementation of an operational control system which will bring to the attention of a company all the necessary information. Also efforts must be made to design a system to disseminate this information to the proper people.

Conclusions

I believe that some broad conclusions may be made from this study. They indicate where the emphasis of thinking should be placed. The first conclusion is that an oil company will make the best decisions as to the method of procuring its required tonnage if it can determine: a) its own cost of capital, b) the relationship by which the level of spot rates are determined, and c) the policy by which operatives in the market order new ships.

Second, it seems that the randomness of demand for oil around the forecast, the growth rate of demand, and the level of the seasonal variation of demand are not as important as the above. Therefore, the information system of the oil company should not concentrate on these values.
Finally, I feel that we have shown that the timing by which an oil company orders vessels can make a large difference in the price it pays for transportation.
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APPENDIX I

Sample Computer Output

In this appendix will be shown a sample of the computer output of the programmed model. In the example used are the results of test 8, model 5, which are shown in three sheets.

Sheet 1 gives the tabulation of the equivalent monthly cost, (EMC), and the break-even long term charter rate, (LTC), for the various alternatives. Sheet 2 shows the plots of demand for oil transportation, (DEMT=T), and the supply of tankers, (SUPLY=S), generated by the model. Sheet 3 shows the plots of the spot rate index, (WQPCH=§); the order rate for new ships, (ORDER=O); the price of new ships, (EQPSH=*); and the production rate of new ships, (PR=P), developed by the model.