MODERN FLEET PLANNING METHODS FOR OCEAN LINER SERVICE

by

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Bachelor of Science in Mechanical Engineering
University of Iceland, 1989

Submitted to the Department of Ocean Engineering
in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Ocean Systems Management

and

Master of Science in Transportation

at the
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ABSTRACT

This thesis introduces modern methods for use in fleet planning for ocean liner service. It begins by reviewing the classical issues such as the methodology of fleet studies, finance, and economics, and modern planning methods such as linear programming.

It then introduces new measures and concepts to improve the way fleet planning is currently done. The measures are both operation and service quality measures. These measures were developed in this thesis so as to tie together the goals and constraints of the carrier and the needs of freight owners. These are often contradictory to each other.

A computer program for optimizing fleet planning, FLEET IMPACT, was then developed in order to apply these measures effectively. The program's source code was written in the Pascal computer language.

FLEET IMPACT, which has a built-in Linear Programming solver, is then used to optimize an on-board space allocation model. The software's use in analyzing an ocean liner's route in terms of logistics and operations performance, is also demonstrated.

Examples of the use of Linear Programming in optimizing fleet capacity allocation, and the Graphical Evaluation and Review Technique (GERT) for schedule analysis, are then shown.

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1. OVERVIEW OF FLEET PLANNING

1.1. GENERAL DISCUSSION

The primary objective of fleet planning is to establish one or more alternative strategies and to evaluate their potential financial impact.

Fleet planning has to take into account a range of information, extending from hard data to subjective opinions. At one end of the risk spectrum is the performance and route analysis information which is well established. At the other extreme are expectations about competitive positions and a changing environment.

When the necessary data has been gathered, a fleet study can be prepared to establish one or more alternative strategies, which can then be compared by doing a financial evaluation.

Fleet planning relates to what ships to buy, how many, when to buy them and/or retire them, where to deploy them, and what cost and revenue estimates are. The decisions require both short and long term action so a less detailed or aggregate approach is desirable.

The variables and interrelated decisions that affect fleet planning may be so many that a simultaneous approach is not practical. The alternative is to divide the problem into a system of separate categories which are more manageable.
1.2. THE METHODOLOGY OF FLEET STUDIES

1.2.1. THE EIGHT FUNDAMENTAL STEPS

There are eight fundamental steps to go through when a fleet plan is being studied. They are:

1. Establish baseline case
2. Choose evaluation criteria
3. Formulate alternative strategies
4. Evaluate alternatives
5. Sensitivity analysis
6. Short listing
7. Working plans
8. Decide action

1. Establish baseline case

This is how things are currently, and what is to be improved. It is sometimes referred to as the "do nothing" case. Often it turns out to be the best option. Any alternative plan usually involves some degree of risk, so a significant potential improvement is needed over the base case before acting, assuming that the current position is satisfactory.
2. Choose evaluation criteria

   If a company is profit oriented, it may choose a factor such as to maximize the Net Present Value (NPV) after tax. If there are no revenues, it may choose to minimize the NPV of costs.

3. Formulate alternative strategies

   Here possible and practical alternative approaches are considered, possible meaning what can be done, practical meaning whether it makes sense. The range of alternatives should be rationalized and reduced to a workable number.

4. Evaluate alternatives

   Here the workability of the options are assessed. How many ships are needed to satisfy the freight forecast, and when are they needed? What are revenues and costs, and how much investment is needed? And how do the alternatives perform in terms of the chosen evaluation criteria?

5. Sensitivity analysis

   The estimated outcome from the calculations depends on the many assumptions made. Any one of them could change the results and, what's more important, the ranking order of alternatives. Assumptions used in making freight forecasts are important, and so are assumptions about freight rates and cost inflation. Sensitivity analysis gives a broad measure of the risks involved in implementing a particular plan, without the complexities of an in-depth risk analysis, which would require
assigning probabilities to the various input values to obtain a range of likely outcomes.

6. Short listing

At any stage in the analysis, some alternatives can be rejected as being impractical, or too expensive, because of constraints. At this stage the choice is likely to be between a close group of alternatives. Any alternative worse than the present plan can be rejected. Other plans can be rejected because of insufficient time for analysis.

7. Working plans

Here a working plan is developed for the final contenders. Few uncertainties remain and the decision will be made with full knowledge of the likely consequences.

8. Decide action

Finally, it becomes necessary to decide what to do. The planning process should not be started unless the decision makers are seriously prepared to implement their findings.
1.2.2. THE AGGREGATE AND DETAILED METHODS

To explain the difference between the two, one can imagine an island nation midway between two trading blocs such as Europe and the United States.

The *detailed*, or bottom-up method for fleet planning would be to take each port pair, one port being on the island and the other in either trade bloc, and analyze and forecast freight traffic between them over a certain time horizon, e.g. with industrial analysis. The results could be statistics such as an average and a standard deviation of the freight traffic. This would then be added up to get the necessary total freight capacity on each link of the proposed route.

The *aggregate*, or top-down method would be to analyze future trade between the island and each bloc, based among other things on economic forecasts, and then come to a conclusion about total freight traffic to and from the island on each side, and then somehow divide that traffic between the port pairs.

Both methods should be used, but the aggregate method should be emphasized more if, for example, currency exchange fluctuations are likely to affect which trade bloc becomes more important for the island. The detailed method would be more important if freight traffic within a nation was being analyzed. An example of that would be freight traffic forecasting between New York and Norfolk.
1.3. POLICY AND THE POLITICS OF TRANSPORT

Government participation in the transport industry has a dual role: promotion and regulation. A viable transport network is vital to commerce. For this reason, communities and government provide promotion and subsidies to portions of the industry and may actually operate parts of the transport system (e.g. air traffic control, port management).

Regulation varies by area of transport and seems to depend somewhat on the political lobbying power of the transport mode’s customers. Ocean liners seem to be less regulated than other modes. They are, for example, sometimes ignored when they form pricing cartels ("conventions") to reduce excess capacity in certain markets. This is possible only because freight customers are relatively few, have little clout and represent a limited number of votes. Airlines are a different story. More than eight out of ten people in the United States travel with airplanes, and most of these people are voters. This is a group that lawmakers and government officials fear and respect. As a result, airlines are severely punished for price and capacity fixing.

Current regulation is of two forms. The first is non-economic, covering issues of safety, registration and environmental protection. The second form is economic regulation controlling rates and competition. In recent years regulation has been relaxed to reduce or eliminate many of the inefficiencies in the transport sector caused by it. Less regulation reduces many entry and exit barriers in the
industry and allows significant restructuring to take place. This results in increased competition, lower and more flexible rates, and greater operating efficiencies. If rates are allowed to be more flexible, they can allow improvements such as those discussed in later chapters. On the other hand, too little regulation may create monopolies, especially if economies of scale are significant in the industry.

It is of interest to know how much active competition, or concentration there is in certain transport markets, and also to observe those trends over time. There are various measures available for that purpose. The one considered most accurate is the Hirschmann-Herfindahl Index (HHI), used by the United States Department of Justice (US-DOJ) to investigate planned mergers and monopoly behavior. It is defined as:

\[ HHI = \sum_i (MS_i)^2, \text{ i = over all firms in market} \]  

(1-1)

where \( MS_i \) is the percent market share of firm \( i \), and \( i \) is taken over all firms competing in a particular Origin-Destination (O-D) market (see Ch. 1.4.1. for the definition of an O-D market). Note that competition is on the O-D level, not the route level. The HHI-index varies from 1 for perfect competition, to 10,000 for complete monopoly. The US-DOJ guidelines say that if HHI is less than 1000 there is sufficient competition, but if it is larger than 2000, the market will show signs of monopoly behaviour.
The formula’s purpose can be reversed. An ocean liner doing fleet planning may want to enter a certain O-D market. By calculating the HHI-index it can see how competitive that market is compared to other O-D markets it operates in, and partly on that basis decide whether it is worth entering.

Note that the firms included as effective competitors are not necessarily in the same transport mode, so a trucking firm operating in the same O-D market as an ocean liner would be included as a competitor in the HHI formula.

Firms have differing policies that are a result of the environment they operate in. A company may have a policy on competitiveness which says that competitors should not be met head-on. It may be too small to survive an angry competitor. Or, in case of a large dominating ocean liner operating in an unregulated environment, it may be afraid to compete intensively with its few and small competitors because that might put the firm in a monopoly position, with resulting government regulation of rates and route structure. That same ocean liner may also want to service small unprofitable ports within its national boundaries to disprove the theory that regulation of rates and routes is necessary to guarantee service to those same ports. Instead it reaps the benefits of deregulation elsewhere. There may be other advantages in "cooperating" with the government and communities, e.g. the government may agree to deepen ports, lengthen piers, etc., enabling the ocean liner to use larger, more efficient ships on its routes.
Factors such as these will affect the company's objective or objective function, which instead of being "to maximize the long term profits of the firm" might be "to have some profits, but not too much since that might lead to regulation". The difficulty of using rigorous mathematical methods for fleet planning under those circumstances is obvious.
1.4. THE FLEET PLANNING COMPONENTS

The main fleet planning components are Route analysis, Freight forecasting, and Financing and economics.

1.4.1. ROUTE ANALYSIS

Route analysis includes distances between ports, port restrictions on ship size and pollution, voyage time, and turnaround time. Other important things are unloading and loading equipment available in the ports, overcrowding that could cause delays, schedule constraints, and what ships are available for the route. It is also important to be aware of unusual route problems such as ice and bad storms in the winter. It would be unwise to put a ship designed for the Mexican Gulf, on certain North Atlantic routes unless it was strengthened for ice collisions. In view of the above it is also necessary to ask what-if questions, that is, if problems come up, how flexible will the fleet be. The fleet has to be flexible not only to crisis situations, but also to future changes in demand.

If the ships have to sail through shallow waters or narrow channels, this might slow them down, and even more so if the ships are large. Distances between ports also affects the size of ships. In general, the longer the stage length is, the larger the ship can be. In other words, if the route is short, the advantage of size is reduced. The benefits of ship size are only seen while cruising, not while in
port. No savings per container are seen in port because port time is proportional to containers unloaded and loaded. Port tariffs are actually higher for larger ships.

For every port pair served there are two markets, one in each direction. Each of these one-way markets is called an *Origin-Destination market*, or *O-D market*. They may have nothing in common, i.e. the type of commodities flowing between them and the freight rates may be entirely different. The potential number of markets when port call is made in n ports is:

\[
\# \text{O-D markets} = n \times (n-1) \tag{1-2}
\]

so if calls are made in five ports, the number of servable O-D markets is 20. A firm may not be interested in, or might not be allowed to operate in all of these markets. This might happen when operating in a regulated environment, or if the O-D market in question is completely within the national boundaries of a nation foreign to the firm. As deregulation becomes more common around the world, such markets will open up to outsiders. Therefore it becomes more and more important for firms to be aware of imminent new market opportunities, and the fleet plan may have to take account of them. The number of markets served must be somewhat limited though so that the firm and its management can remain focused on their core business.

It might be tempting for an ocean liner to add port calls to a route, especially in view of the formula above. If only one port call is
added to a route with five ports, the number of additional servable markets would go from 20 to 30, resulting in revenue increases and load factor improvements. The marginal cost of making that port call might seem small, but the service quality for other O-D markets on that route could suffer, and there would also be a network displacement cost (see Ch. 2.3.1). Hence the need for route or network service quality measures such as those introduced in Chapter 2.2.

Feasibility studies of feeder service are an important part of route analysis. An efficient feeder service can reduce costs significantly, and open markets that otherwise might have been too costly to serve. With feeder service freight travel time between port pairs may actually increase, but instead the frequency of service can often be improved, resulting in shorter overall trip time, that is, in-transit time plus terminal wait time. The cost savings come through economies of scope, when economies of ship size are greater than the additional cost of rerouting the freight. Larger ships are more efficient because of savings in crew costs, and because of ship hydrodynamics effects, when resistance per displacement unit is reduced as the ship becomes larger.

Cost savings with feeder service are also seen because of another factor of a statistical nature. It can be seen when multiple O-D markets use the same route link as is the fact in feeder operations. The freight traffic fluctuation, or variance, in the combined route link is proportionally less than the variation in each market if they were
served separately. This leads to less wasted space and higher load factors without a reduction in space availability. Space availability as a service quality measure is defined in Chapter 1.4.2.

Frequency of service is an important decision variable. A trade-off must be made between an expensive high frequency service, and a low frequency service with economies of scale. It is difficult to do the right amount of trade-off without understanding and analyzing customer logistics. The measures introduced in Chapters 2.1. and 2.2. are essential to a frequency-of-service analysis.

To explain the importance of frequency of service analysis, one can take a port-pair market served by one ship, where the roundtrip takes 4 weeks. Assuming that the freight arrives randomly at the terminal, the average in-terminal wait time would be half of that, or 2 weeks. Therefore the total travel time (in-terminal wait plus voyage time), which is what the customer worries about, is 4 weeks. Doubling the frequency to a bi-weekly service, using two ships with the same service speed as before, reduces the average trip time to 3 weeks, tripling the service with three ships gives a trip time of 2.7 weeks, and quadrupling frequency (four ships, same service speed) to a weekly service would put total trip time at 2.5 weeks. This explains the concept of frequency saturation. It happens because an increased frequency of service only shortens the in-terminal wait time and not the voyage time. As important as such an analysis can be, it is still important to notice that in very competitive markets the frequency of service is often determined by the largest competitors. A high frequency
of service will probably be matched by other companies in the market, since they will otherwise lose market share. Other things being equal, increased frequency of service increases market share, and decreased frequency reduces market share. But if all competing firms move in tandem, market share will neither be lost nor gained.

Frequency saturation is reached sooner in long-haul markets such as the North-Atlantic. Because of that they tend to have a low frequency of service and large ships, while short-haul (or short-sea) markets have smaller ships and a high frequency of service. Port pairs in the Baltic Sea are an example of such short-haul markets.

1.4.2. FREIGHT FORECASTING

When doing forecasting for a well-established market, experience shows that simple mathematical methods work just as well as more sophisticated ones. If a newer market is being studied it makes sense to focus less on forecasting from past data and more on strategy and industrial analysis of those markets.

When handling past data, certain points must be kept in mind. One is that demand for freight transport is unaffected by the fleet capacity allocated (as long as it does not restrain demand). Demand is affected by the frequency of service, the schedule of services, its reliability, cost of service, convenience of service (intermodal transport is strong here, see Ch. 2.1.3.), loss and damage history, and possibly the status of quality control procedures, as many companies do not ship products
with carriers that lack certified quality control procedures. The company's attitude towards environmental protection may also help it gain or lose customers.

In addition to the above, demand may be affected by acts of God and Economics. Past data must therefore be scrutinized with respect to unusual events such as war and bad weather, labor strikes, recessions and currency exchange fluctuations, and changes in competitive postures (new competitors entered, or old ones exited, etc). Free trade agreements and regulation changes may also suddenly and drastically change trade patterns and mode favorability. Any sudden unexplained behaviour and abnormalities in past data must be removed from the analysis. Finally, demand can be affected by changes in other modes, e.g. if new road taxes would be put on trucks, some of the trucking freight traffic losses would undoubtedly show up on ships. Hence the need to understand the dynamics of other transport modes.

It is important to analyze past data statistically. Finding simple numbers such as the standard deviation of freight demand in each Origin-Destination market can help define service quality. If the standard deviation of the data is not known, it becomes hard to define important quality of service factors such as space availability, which says how likely a customer is to get space for one standard sized container (one Twenty-foot Equivalent Unit, TEU) on board if it arrives just before the delivery deadline. An example of defining the service quality would be to say that planned capacity should be set at the average demand plus
three standard deviations. At that capacity level the space availability would be 99%.

Standard deviation enters the picture in another important way. If two or more O-D markets use the same route link, the relative standard deviation of that link is less than the standard deviation of traffic data for each market separately. In other words, the sum of markets has less relative fluctuation than each market separately. The total capacity needed for the joint route is therefore less than the sum of the capacities needed for each market if they were serviced with separate routes. This leads to higher average load factors. The above reason is one of the main arguments for feeder service in ocean transport. If the average and standard deviation of demand for O-D market 1 is $x_1$ and $\sigma_1$, and for market 2 is $x_2$ and $\sigma_2$, then the average and standard deviation for the combined demand would be:

$$x = x_1 + x_2 + \ldots + x_N$$  \hfill (1-3)

$$\sigma = \left[\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_N^2\right]^{0.5} / \sqrt{N}$$  \hfill (1-4)

where $N$ is the number of distributions or markets served. By looking at the formula for the average, this larger average will translate into economies of scale for the firm, while the formula for the combined standard deviation shows that as the number of markets served increases,
the standard deviation is reduced. A comparison of the two cases, that is markets served jointly on a route link and then separately, follows.

Combining two markets with average 50 and 80 TEUs, and standard deviations of 8 and 12 TEUs, gives a combined average of 130 TEUs and a standard deviation of 10.2 TEUs according to formulas (1-3) and (1-4). If the service quality standard specifies that space availability should be 99%, the assigned capacity for the combined route would be the average plus three standard deviations, or \(130 + 3 \times 10.2 = 161\) TEUs. Assuming there were no rejected containers, the average load factor would be the average demand divided by capacity or \(130/161 = 0.81\).

If the markets were served separately, market 1 would need a capacity of 74 TEUs (average + 3 standard deviations), and market 2 would need 116 TEUs. The load factor for market 1 would be 0.68, and for market 2 it would be 0.69. The average load factor would be 0.685 which is significantly lower than the load factor of 0.81 achieved for the combined market. A lower load factor obviously means less efficiency. Note that the example assumes that the two markets are side by side. This example demonstrates well how efficiency can be increased by serving multiple O-D markets with the same route or route links(s).

When planning future capacity, the freight estimates used must be based on *unconstrained demand*, and not *constrained demand*. Constrained demand is the amount of cargo that was actually carried, but not the amount of cargo space needed, since some of those trips may have been full and cargo had to be turned away or delayed. If constrained demand is used for planning, it may lead to undercapacity and lost revenues.
since containers will either be turned away or will have to wait until
the next trip. This is because the average and standard deviation of the
constrained demand are lower than for unconstrained demand.

It is easy to change constrained demand to unconstrained by
putting constrained demand on a log chart of the normal distribution
curve, with capacity on the y-axis and log of the cumulative frequency
distribution on the x-axis, eliminate the data points that are
constrained, i.e. those data points representing full ships, and then
drawing a straight line through the data. The results would give the
average and standard deviation of the unconstrained demand which can
then be used to design route capacity. It would be better to carry a
list of rejected containers, that is, of those containers that had to
wait for the next trip, or were sent with other means because there was
no space on board. Rejected plus carried containers, avoiding double-
counting, of course, can then be used as unconstrained demand, and the
above statistical manipulation would be unnecessary.
1.4.3. FINANCING AND ECONOMICS

Financial and economic data may be operating costs per day when cruising, when in port, port tariffs, ship and container depreciation, and interest and insurance. On the revenue side are achievable freight rates by cargo type and market.

Three important parts of an investment decision are how much to invest, which assets to invest in, and when. The objective is to acquire assets whose value to the company and its owners exceeds their costs. When choosing between mutually exclusive investments, the Net Present Value (NPV) method is the only reasonable way to maximize value to shareholders. Other methods such as the Net Present Value Index, Internal Rate of Return and the Payback method can lead to inferior decisions. The following points are highlighted to ensure proper application of the NPV criterion.

1. Cash flows should be computed on an incremental basis. Sunk costs should be excluded. Overhead costs should not be included unless they are generated by the investment under investigation.

2. All external effects should be included. Initiation of service on a new route, for example, may have a negative NPV if the route is considered in isolation. From the point of view of the entire network, however, the new route may provide a positive NPV, once the network effect is considered.
3. Opportunity costs should be included in the analysis. The decision of whether or not to buy a new ship, for example, should take into consideration the opportunity cost of using retained earnings, if this source is part of financing the investment.

4. Inflation should be treated consistently. Nominal cash-flow forecasts should be discounted at nominal rates and real forecasts at real rates.

5. A positive NPV for an investment made at present may not necessarily yield the optimum return. The NPV might be much higher if the investment is delayed. It is prudent to examine a number of possible investment dates.

6. If two or more projects interact, their analysis should be performed concurrently.

7. If the financing decision has an influence on the investment decision, the two should be considered jointly. The source of financing influences cash flows, the discount rate, and the amount available for the total investment program.

8. After-tax cash flows should be used. Accounting data should be avoided in cash-flow analysis. Calculations should include all incremental cash flows.
9. Because future returns are unpredictable, risk must be considered in the estimation of cash flows, such as with decision-trees, or by estimating the standard deviation of the distribution of possible outcomes relating to future returns.

10. The opportunity cost of capital (OCC) that should be used is directly related to the firm's cost of capital, the risk associated with the firm's securities, and other available investment options in the marketplace. The same OCC should be used for all the firm's investments. A more risky investment should not be discounted with a higher OCC, but should instead be risk-corrected with cash flow risk analysis.

   Prudent investment planning should go further than this. Sensitivity analysis is important since uncertainty remains a major issue in any analysis. Uncertainty is small in the routine replacement investment but large in a major strategic investment. This means that the importance of the financial analysis as part of the final decision decreases as risk increases. Net Present Value analysis should weigh heavily if doing fleet planning for a well established route with stable demand, but less for new and risky routes.

   The sources of funds for fleet financing are many, and may affect the outcome of the NPV analysis. In general the investment analysis should be done without concern for the financing part. But if the
financing part is affected by the choice of fleet, such as if certain shipyards offer subsidized financing, it should be included in the investment analysis.

Sources of fleet financing are either from internal funds, such as Net Income, Depreciation, and Deferred Taxes, or they come from external funds, through either Debt Financing where the firm borrows money, or Equity Financing when outside investors "lend" the firm money in exchange for an ownership stake.
2. MODERN ISSUES IN FLEET PLANNING

2.1. CORPORATE LOGISTICS

2.1.1. CUSTOMER LOGISTICS

Logistics is important because it is the driving force underlying the demand for freight transport. Bowersox has defined logistics as:

*The process of strategically managing the movement and storage of materials, parts, and finished inventory from suppliers, between enterprise facilities and to customers.* [Bowersox, 1976]

In fleet planning it is necessary to look at how the cargo owner’s logistics are affected by the various fleet plans. The needs of both large and small customers must be taken into consideration. It is not a good idea to focus only on minimizing the carrier’s cost of operating the fleet, what customers are more concerned about is the balance between freight rates and the fleet’s schedule of services. Higher freight rates, or a better competitive position (e.g. increased market share) can be achieved with a more convenient schedule. A more convenient schedule can be achieved with faster ships, more efficient routing and a higher frequency of service. Increased speed at sea should only be selected if the schedule, time of departure, or frequency on the route are improved. Speed at sea has no value in itself, it only
increases costs. The following list summarizes some general factors which encourage higher ship speeds in ocean transport.

- High value cargoes. Note the opposite: low value cargoes cannot afford to travel at the highest speeds

- High freight rates: the ship carries greater amounts of high-earning cargo over a period. Note the opposite: when freights are low, ship speeds are often reduced

- Short turnaround time: increasing the proportion of time at sea when the higher speed can be used

- Cheaper fuel, or fuel costs rising slower than other parts of income and expenditure

- High interest rates, so that high capital charges on the ship are spread over more voyages per year

- High daily operating costs, e.g. crew: increasing productivity per unit time

- Shortage of ships: greater transport capability obtained per unit investment, at the expense of greater operating costs

- Increased competition
It is important for carriers and their customers to work together to keep logistics costs low in the whole logistics channel, from raw materials producers to the retail level. The largest companies in such channels, so-called channel captains, are often the driving force behind these cooperative efforts. Ocean liners are often part of these channels and can be such a driving force, and must understand the importance of the value of time. If trip time for freight is increased, the logistics channel may have to carry more inventory, which leads to higher inventory interest expenses, and more depreciation in the case of perishable products. Having an optimum fleet schedule for the customer may increase costs for the ocean liner but customers should be willing to pay higher rates because of reduced inventory costs and better service. An analysis of customer's needs, including logistics costs, must be done to the extent possible.

One way of analyzing the routes in terms of customer's needs would be to estimate the average value of goods in each container, and then apply measures such as Revenue Container-days (RCDs), introduced in Ch. 2.2.2. and applied in FLEET IMPACT in Ch. 3, to estimate the total logistics cost for a planned transport network. This analysis would also be done for each port pair, the idea being that the total network RCDs should be kept low, subject to each port pair having "adequate" service. The NPV of each fleet plan could then be modified to account for customer's logistics costs savings, for a more realistic comparison. The NPV modification would appear as increased revenues since customers should be willing to pay higher rates for improved service.
It is important to realize that in-transit inventory cost reductions are not only made when RCDs go down but also in other parts of the inventory channel. This becomes apparent when the logistics cost function, introduced next, is studied. This amount would be more difficult to estimate, RCDs would therefore give a lower boundary on savings.

2.1.2. A LOGISTICS COST FUNCTION*

In order to better understand the needs of freight owners, and the advantages and disadvantages of other competing modes, a simple logistics cost function is presented. The cost function is developed for a commodity flowing between two suppliers, each of which has an inventory. The most important costs are as follows:

<table>
<thead>
<tr>
<th>ORDER</th>
<th>Order cost, i.e. the cost of arranging a shipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOAD</td>
<td>Loading cost</td>
</tr>
<tr>
<td>UNLOAD</td>
<td>Unloading cost</td>
</tr>
<tr>
<td>TRANSPORT</td>
<td>Transport cost, i.e. the direct cost or price of transporting a shipment</td>
</tr>
<tr>
<td>O_INVENTORY</td>
<td>Origin inventory, i.e. the cost associated with the inventory that may be required at the origin</td>
</tr>
<tr>
<td>IN_TRANSIT</td>
<td>In-transit inventory, i.e. the cost associated with the freight as it moves from origin to destination</td>
</tr>
</tbody>
</table>

* Based on lecture notes in 1.286 Freight Transportation Management, C.D. Martland, Jan. 1992. [See Ref. 11]
D_INVENTORY  Destination inventory, i.e. the cost associated with the inventory that may be required at the destination

SAFETY_STOCK  Additional inventory that may be required at the destination in order to guard against late shipments

STOCKOUT  The cost incurred if a shipment is late and there is a stockout

L&D  The cost associated with loss and damage during loading, transit, or unloading

PERISH  Perishability, i.e. the costs associated with the potential loss of value of freight over time, either because of a decline in quality, or value

It is possible to express each of these costs in terms of the following variables, drawing in large part upon Roberts [1975]:

a. Freight owner characteristics:
   
   S = Annual use rate of the receiver
   
   i = Inventory carrying costs

b. Commodity attributes:
   
   V = Value per pound
   D = Density
   L = Shelf life
c. **Transport attributes:**

\[
X = \text{Shipment size} \\
P = \text{Price} \\
T = \text{Average trip time} \\
\sigma = \text{Standard deviation of trip time} \\
a = \text{Fixed price per shipment} \\
b = \text{Variable cost per shipment unit}
\]

**ORDER:** The ordering cost will often be constant for a wide range of shipment sizes, so the annual cost will be the unit ordering cost multiplied by the number of shipments:

\[
\text{ORDER} = C_1 \times (S/X)
\]

**LOAD and UNLOAD:** This is assumed to be a constant multiplied by the annual use rate, such as in the case of container transport where unloading and loading is fixed in dollars per container:

\[
\text{LOAD} = C_2 \times S \\
\text{UNLOAD} = C_3 \times S
\]

**TRANSPORT:** Here the cost is assumed to be a fixed price per shipment plus a variable cost depending upon shipment size:

\[
\text{TRANSPORT} = a + b \times X \quad (2-1)
\]
Note that a is not just a monetary value but also includes an "effort cost", that is, the inconvenience cost of making an order.

\[ O_{\text{INVENTORY}}: \text{The inventory at the origin is a function of the production rate and the shipment size. If production is constant, and if everything is shipped from A to point B as soon as a complete shipment is available, then there will, on average, be half a shipment in inventory.} \]

The inventory carrying cost is usually expressed as the product of the value of the inventory and a capital carrying rate that reflects the time value of money, insurance costs, and warehousing costs:

\[ O_{\text{INVENTORY}} = i \times V \times (X/2) \]

**IN\_TRANSIT**: This is the opportunity cost to the owner of the freight during the transport of the shipment. On average, each unit of freight will be in transit \( T \) days, so that the annual cost will be the product of the annual use rate \( S \), the value per pound \( V \), and the capital carrying cost for the time spent in transit:

\[ \text{IN\_TRANSIT} = S \times V \times i \times T/365 \]

**D\_INVENTORY**: This is the cost of holding inventory at the destination. If the commodity is used continuously and replenished just as the inventory is about to be depleted, then the average inventory will be half the shipment size, and the costs will be as in the equation
for 0_INVENTORY (note that the capital carrying rate \( i \) may be different):

\[
D_{\text{INVENTORY}} = i \times V \times (X/2) \tag{2-2}
\]

SAFETY_STOCK: Normally some additional inventory will be carried to guard against the possibility of production delays or a late shipment, or of greater than expected demand for the commodity while the shipment is en route. If only the transit time is variable, then the receiver can hold "a few days" additional inventory to guard against late arrivals. For example, if the standard deviation of the trip time is \( \sigma \), then the cost of safety stock, which would be carried year-round, is:

\[
\text{SAFETY_STOCK} = i \times V \times (k \times \sigma) \times (S/365)
\]

Here \( k \) is any number larger than zero. If \( k \) was 3, the safety stock size would be three standard deviations.

STOCKOUT: In practice, both the possibility of a stockout and the cost of it are quite complex. Here it is assumed that the exposure to stockouts is proportional to the number of shipments:

\[
\text{STOCKOUT} = c_4 \times (S/X)
\]
L&D: Like stockouts, loss and damage is highly specific to the commodity and situation. The normal approach is to estimate L&D as a fraction of the total value of the shipments:

\[
L&D = C_5 \cdot V \cdot S
\]

PERISH: Perishability is a special form of L&D that relates to the loss of value because of lateness of arrival. For most commodities this is not a major concern, but for some, such as fresh fish and other perishables, it can be the dominant concern. One way to express a perishability cost is by depreciating the product value by a certain percentage per day of trip time:

\[
PERISH = C_6 \cdot V \cdot S \cdot T \quad (2-3)
\]

This is how the perishability of cargo is estimated in the fleet planning program FLEET IMPACT, which was developed as part of this thesis (see Ch. 3).

Total logistics costs are the sum of the simplified cost elements above. In the case of an ocean liner whose main cargo is containerized fresh fish, perishability becomes an overwhelming part of customer's total logistics costs. This happens especially when the fishing vessels plan their tour so that they bring in the catch just before departure, and auction the fish as soon as it is unloaded at its destination port,
so that there will be no origin or destination inventories. If a company exports fresh fish worth $35M a year and pays an interest of 20%, the in-transit inventory expenses are just over 19 thousand dollars per year for each trip-day. The perishability on the other hand, assuming a moderate decline in value of 5% per trip-day, would be 1.75 million dollars per year for each trip-day. If the trip time between two ports is reduced by one day, this would be the amount the fish exporter would save. Instead the ocean liner should be able to raise freight rates to cover the increased cost of providing better service. An example like this demonstrates the need for analysis of customer logistics.

It is of interest to the ocean liner to understand how customers determine their shipment size and frequency of shipments. The Economic Order Quantity (EOQ) is commonly used to illustrate this. If only the transport price (formula 2-1) and the inventory costs at the destination (formula 2-2) are considered (note that total in-transit inventory expenses do not vary with order quantity X), the receiver’s logistics costs will be:

\[
\text{LOG} = \frac{S}{X} \times (a + b \times X) + i \times V \times \frac{X}{2}
\]

Differentiating with respect to shipment size X to find a minimum, and isolating X gives:

\[
X(D_{\text{INV}}) = EOQ = \left[\frac{2 \times a \times S}{i \times V}\right]^{0.5}
\]
This says that the EOQ increases with the fixed transport cost per shipment, a, and annual use rate, S, but decreases with the value of the product, V, and the capital carrying/warehousing cost, i. To gain further insight into channel logistics costs it is of interest to present the EOQ formula in the case where inventory is at both origin and destination:

\[ X(D_{INV}+O_{INV}) = EOQ = \left(\frac{a \times S}{i \times V}\right)^{0.5} \]

Here \( X(D_{INV}+O_{INV}) = 0.71 \times X(D_{INV}) \). The optimum order amount is 71% of the amount that companies would normally order since they do not "see" the origin inventory. As a result the firm orders 29% too seldom and total logistics costs, which the end-user eventually pays for, become larger than necessary. Hence the need for cooperation in the logistics channel, as discussed previously. These are, of course, not the only transport related factors that affect inventory expenses. For example, the amount of inventory safety stock needed is directly related to the reliability of the transport service.
2.1.3. INTERMODAL TRANSPORT

The main transport modes are ship, truck, rail, aircraft, and pipeline. Intermodal transport can also be considered a separate mode.

Intermodal transport is a fast growing segment in the transport industry. Not only are shippers using more than one mode to meet their transport needs, but freight carriers are increasingly offering "one-stop shopping".

Intermodal transport combines the service and cost characteristics of each component mode. The most common forms combine trucking with another mode. These combinations provide the short-haul and accessibility advantages of trucking with the low-cost service of water or rail, or the speed of air transport. In a truck/water combination, truck trailers can be driven onto ships, to form an intermodal combination known as roll-on roll-off, or RORO.

Containerization has facilitated the move toward intermodal transport. Containers allow the mechanization of intermodal transfers, reduce damage and theft, and reduce handling costs. Most containers are about the size of a truck trailer and can be carried by truck, ship or rail. Special containers designed to fit airplane holds are also in use.

There are drawbacks associated with the use of containers. Most cranes for lifting and transferring containers are limited in capacity.
Also, the weight of the container itself increases the cost of transport. In addition, empty containers must be tracked and returned, and the scheduling of containers can be a complex task.

When doing fleet planning for ocean transport it is necessary to understand the relative strength of that mode to other competing modes. The following two pages summarize these differences.
INTERMODAL COMPARISONS

<table>
<thead>
<tr>
<th>Mode</th>
<th>Advantages/Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermodal</td>
<td>Combines advantages of two modes</td>
</tr>
<tr>
<td></td>
<td>Low damage and loss</td>
</tr>
<tr>
<td></td>
<td>Increased efficiency and cost economies</td>
</tr>
<tr>
<td>Water</td>
<td>Mass movement of bulk commodities</td>
</tr>
<tr>
<td></td>
<td>High capacity</td>
</tr>
<tr>
<td></td>
<td>Lowest cost</td>
</tr>
<tr>
<td></td>
<td>Excellent for long-haul movement of low-value commodities</td>
</tr>
<tr>
<td>Truck</td>
<td>Extensive geographic coverage provides point-to-point service</td>
</tr>
<tr>
<td></td>
<td>Capacity to handle all types of goods</td>
</tr>
<tr>
<td></td>
<td>Fast and flexible</td>
</tr>
<tr>
<td></td>
<td>Frequent departures</td>
</tr>
<tr>
<td>Air</td>
<td>Fastest mode for intermediate and long movements</td>
</tr>
<tr>
<td></td>
<td>Low damage and loss</td>
</tr>
<tr>
<td>Rail</td>
<td>Mass movement of goods</td>
</tr>
<tr>
<td></td>
<td>High capacity</td>
</tr>
<tr>
<td></td>
<td>Wide geographic coverage</td>
</tr>
<tr>
<td></td>
<td>Low unit costs</td>
</tr>
<tr>
<td></td>
<td>Energy efficient</td>
</tr>
<tr>
<td>Pipeline</td>
<td>Mass movement of liquid and gas products</td>
</tr>
<tr>
<td></td>
<td>High capacity</td>
</tr>
<tr>
<td></td>
<td>Very dependable</td>
</tr>
<tr>
<td></td>
<td>Lowest operating and unit costs</td>
</tr>
</tbody>
</table>

## COMPARATIVE RATINGS OF TRANSPORT MODES

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Greatest</th>
<th>Least</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (Origin to Dest.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 500 miles</td>
<td>Truck</td>
<td>WATER</td>
</tr>
<tr>
<td>Over 500 miles</td>
<td>Air</td>
<td>Pipeline</td>
</tr>
<tr>
<td>Versatility (Load size and type)</td>
<td>WATER</td>
<td>Rail</td>
</tr>
<tr>
<td>Geographical availability</td>
<td>Motor</td>
<td>AIR</td>
</tr>
<tr>
<td>Dependability</td>
<td>Pipel.</td>
<td>Truck</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>Pipel.</td>
<td>Truck</td>
</tr>
</tbody>
</table>

2.2. FLEET PERFORMANCE MEASURES

There are various ways to estimate the production, operating efficiency, and service quality of a route or network. These units of efficiency can provide valuable insight into important issues such as logistics and the value of time. They also allow an easy comparison of routes and complicated networks, and are suitable for use in mathematical models.

Some of the measures introduced in this chapter, such as RCDs, RCMs and ACMs, are applied in the FLEET IMPACT fleet planning software (see Ch. 3) that was developed as part of this thesis.

2.2.1. PRODUCTION, EFFICIENCY AND SHARE GAP

The potential production of a ship can be thought of as the product of available space on board, speed of ship, and time proportion used to carry freight, or in formula terms:

\[ \text{Potential prod.} = \text{Capacity} \times \text{Speed} \times \text{Utilization} \]

Production can then be increased by increasing any or all of these factors. The following factors are closely related to the above unit and can be used as estimates of potential production.
Available Container-miles (ACMs) and Available Ton-miles (ATMs) are a measure of available production capacity. An example of the ACM measure would be a container ship with a total capacity of 500 twenty foot containers (500 TEUs) that sails a roundtrip of 700 miles. Its available production capacity per route-cycle is the multiple of distance and space, or 350 thousand ACMs. Available Ton-miles (ATMs) would similarly be a multiplication of the tonnage capacity and route length. Note that these numbers do not measure production, but rather available production capacity. Formally these can be represented as:

\[
\text{ACMs} = (\text{Available TEU container space}) \times \text{Distance}
\]

\[
\text{ATMs} = (\text{Available Ton capacity}) \times \text{Distance}
\]

The ACM and ATM measures can give a good indication of how much production capacity is "out there", and they can easily be compared to similar numbers from other ocean liners, both for benchmarking and competitive purposes. It is easy to divide a company’s ACMs by the total ACMs of all ocean liners competing on a certain route or geographical area to get an available production capacity share figure. It is also used as the denominator in the load factor analysis which gives the space/weight efficiency for the fleet. The ACM measure may not always give exact results. This becomes apparent when the cargo "weighs out", that is, the cargo is so heavy that its weight limits how much goes on board. In that case ATM becomes more suitable. The same results are seen for ATMs when the cargo "cubes out", that is, space is a limit rather than weight.
Revenue Container-miles (RCMs) and Revenue Ton-miles (RTMs) are similar to the previously mentioned units except that they measure the actual production better. It is important to note here that even though RCMs and RTMs can be used to represent production, they are not the carrier’s output. If they were, customers could buy RCMs and RTMs in a market. There is no single output or measure of system output for an ocean liner. The customer wants his cargo moved between two points, the distance, which enters the above units as production, or path taken between the two points does not concern him. In view of the above, the carrier’s actual output is a schedule of services over a network of markets. The units introduced in this chapter are still interesting as overall measures of system activity that occur in the course of providing the firms outputs.

If revenue cargo is 300 TEUs, and it is carried 350 miles, its RCM is: carried TEUs, multiplied by route length, or 105 thousand RCMs. These units have the same "cube out"/"weigh out" weaknesses as the ACMs and ATMs mentioned previously. The formulas are:

\[
\text{RCMs} = (\text{Carried revenue-TEUs}) \times \text{Distance} \\
\text{RTMs} = (\text{Carried revenue-Tons}) \times \text{Distance}
\]

To get the space or weight efficiency (Load Factor) of the fleet, RCMs and RTMs can be divided by ACMs and ATMs, respectively, to get the route or system-wide load factor. This is a good indicator of production efficiency.
The *share gap* is the difference between the firm's supply of ACMs (or ATMs) and its market share. An example would be a company with 23% of the Available Container-miles in a market, and 25% of the container traffic. This would give a positive share gap of 2% for the company, which would indicate better than average performance in that market.

2.2.2. SERVICE QUALITY UNITS

One important factor in service quality is trip time between an Origin-Destination port pair. O-D trip time affects customer logistics such as inventory costs, perishability, etc., and the cost of fleet operations. The unit of trip time is simply time, e.g. 5 days for a certain O-D market. Although this is an important constraint in fleet planning, it does not include cargo amount. Obviously trip time is more critical if 100 TEUs are transported in a certain O-D market than if 2 TEUs are. A better unit would be a multiplier of cargo amount and trip time such as the following units.

*Revenue Container-Days* (RCDs), or *Revenue Ton-Days* (RTDs) can be used to balance O-D trip times over a network. These numbers reflect the importance of large O-D markets in fleet planning, and can be used to compare the logistics quality of the various networks and their O-D markets. The *Value-days* unit introduced later reflects logistics costs better, but is more difficult to calculate than RCDs. RCDs should be chosen if the market cubes out, but RTDs if it weighs out. An example of RCDs is a market with 100 TEUs and a trip time of 3 days, which gives a
market size of 300 RCDs. Total network RCDs would then be the sum of all Origin-Destination markets. The formulas for RCDs and RTDs follow:

$$RCDs = (\text{Carried revenue-TEUs}) \times \text{Trip time}$$

$$RTDs = (\text{Carried revenue-Tons}) \times \text{Trip time}$$

In the formula, Trip time includes half of the port time in originating port of freight, i.e. the loading time, half of port time in destination port, i.e. unloading time, and the voyage time, which would include port time in any intermediate ports.

Value Container-days (VCDs) is a unit which is closely related to logistics costs. The RCD unit introduced previously does not account for the value of the cargo in each container, or of each ton in case of the RTD unit. This unit would use the cargo value to assess the importance of trip time. Trip time is more critical for a container full of laptop computers than a container full of coal. The VCD unit would relate directly to customer logistics costs. The Value Ton-days (VTDs) unit has a similar relationship to VCDs as RCDs have to RTDs (see previous paragraphs). The Value Container-Day unit is measured as follows. The approximate cargo value in each container is multiplied by its trip-days, and this is then added up for all the containers in the whole network. This unit is closely related to customer logistics costs, which would be approximately (VCD * inventory carrying cost per day). Some effort is required to find this unit, RCDs might be a more convenient number, although it would be less accurate.
2.2.3. COST AND REVENUE UNITS

The unit operating cost is a measure of the cost of having production capacity available. Available production capacity is measured in Available Container-miles. The unit operating cost for an ocean liner would therefore be:

\[
\text{Unit Cost} = \frac{\text{Operating costs}}{\text{ACMs}}
\]

It is important to realize that unit costs are not a direct measure of unit production costs since Available Container-miles are not the output of the firm, as mentioned previously.

Unit revenues are a similar measure, but in this case the unit says how much revenues were achieved per available production capacity unit, or:

\[
\text{Unit Revenues} = \frac{\text{Operating Revenues}}{\text{ACMs}}
\]

The units above could also have been presented in ton-mile terms by dividing with Available Ton-miles (ATMs), instead of ACMs. These measures can be used to compare a firm's performance with that of other ocean liners.
2.3. MATHEMATICAL MODELING

2.3.1. OPERATIONS RESEARCH IN FLEET PLANNING

Mathematical modeling is a detailed, or bottom-up type of fleet planning methodology.

The mathematical modeling approach to the fleet planning problem uses linear programming theory to set up a model to represent that part of reality with which the planners are interested in.

When analyzing the results produced by mathematical models, it must be remembered that the results are affected by the constraints applied. The relaxing or strengthening of constraints will affect the results.

In view of the above it should be obvious that it is also necessary to apply experience and judgement.

With the present state of knowledge it is impossible to include all objectives and constraints faced by an ocean carrier in one model. In fact it is debateable whether such a black-box approach will ever be feasible, since humans cannot easily comprehend multiple input-output problems. Instead they like to break problems down and think about a very limited number of objectives and constraints. A carrier must therefore limit the inputs to the model to the most important concerns.
Multiple models with different objectives and constraints can also be solved, and their results used jointly by decision-makers to reach a final decision.

At best, a mathematical model will give the exact results needed to optimize the firm's objectives, at worst the model will give good insight into the dynamics and economics of operations. To build a mathematical model of operations, their details must be carefully mapped. Such mapping can be an important learning experience, and may aid in future decision-making.

Mathematical models can also be used to find a good starting point for a fleet planning problem. The solution from the model can then be developed further with methods that are more tedious, but may represent the real world better.

The types of mathematical modeling techniques available are Linear, Dynamic, and Integer programming.

Linear programming is relatively easy, but is so only because it is very generalized. Software for solving such problems is readily available and formulation is simple. Huge problems can be solved with linear programming and the solution is quickly found with a computer. The problem with this method is that the objective function and constraints must be linear in nature. It is often difficult to put problems in that format because reality is seldom linear. This often
requires a considerable amount of simplification which makes the solution less accurate, since it is often the solution to a slightly different problem.

Dynamic programming can also be very powerful, but they require that the software be specially designed for each individual problem. The solution time also increases fast with problem size, making them impracticable except for the smallest problems. The computing power and the mathematical theory available today limits the usability of dynamic programming.

Integer programming is also a bit restricted. Software is readily available but the computing time increases fast as the problem grows. Integer problems can often be solved as linear programs, which eliminates many shortcomings.

Linear programming is a computational technique. In general the objective function will be of the following form:

Maximize $C_1x_1 + C_2x_2 + \ldots + C_nx_n$

where $C_i$ is a "profit" coefficient, given linear constraints on values of variables $x_1, x_2, \ldots, x_n$, of the form shown on the following page.
Here, $x_i$ can be specified to be an integer.

A mathematical model such as that above can be made more effective by making it dynamic. This is possible if the problem is not too large. This is done by iterating the model, that is, to run the model, and then replace the parameters according to the outcome. This can then be repeated any number of times. The model could then be based less on deterministic inputs than otherwise.

Various objective functions are possible. They will depend on the company’s goals and policies (see Ch. 1.3). The ones chosen by the carrier may contradict each other. Some compromises would then have to be made. Examples of carrier objectives are:

- To maximize contribution to overhead
- To maximize profits
- To maximize market share
- To minimize costs
- To minimize customer logistics costs
The constraints are of a similar nature. A few possibilities follow:

- Upper limit on customer logistics costs
- Lower bound on load factors
- Minimum market share in some O-D markets
- Minimum service quality in each O-D market

Service quality can be space availability, trip time, etc.

The input data required by Operations Research fleet planning models is extensive. These are summarized below:

**Problem description**
- schedule cycle (weekly, bi-weekly)
- planning horizon (quarterly, yearly, peak season)
- name of case, scenario, etc.

**Fleet data - Operations, Economics (by type of ship)**
- no. of ships of each type available to schedule
- fuel expenditure per hour, or per stage
- trip time between ports, given stage length
- variable operating costs per hour or stage
- cargo capacity, by type (break-bulk, container, etc.)
- ownership costs per cycle (fixed overhead costs)
Port data - for each port
- name of port
- port tariffs by ship type/size
- stevedoring costs
- other container handling costs per load/unload

System data
- system overhead costs/cycle
- system overhead costs/RCM
- system overhead costs/origination
- system freight rate structure

Market data - for each O-D market
- net freight revenue
- minimum desired level of service
- projected demand

Route structure data - for each route
- set of permissible routes which can be served
- set of feasible demand paths for feeder service
- voyage time by route
- port stay time by route

Route segment data - by link
- maximum planning load factor, by cargo type
- link length
Following is a general model for fleet planning and capacity allocation. In this example the ocean carrier has decided what ports it will serve, but needs to know which ship to allocate for the route. It also knows the demand for each O-D market along with estimated net revenue per container (could also be per ton), but does not want to serve them all, or wants to know which ones to concentrate on. Since the cost of operating various ships on that route is known, the problem becomes to decide what ship to use, which depends again on what markets will be served. The model is built with three ports, but can easily be extended to any number of ports. The route cycle is 1-2-3-1, etc.

According to formula (1-2) in chapter 1.4.1. where n = 3 ports, the number of O-D markets servable is n * (n-1), or six. The decision variables are \( x_{ij} \) and they represent how many containers should be transported from port \( i \) to port \( j \), that is, in O-D market \( i-j \). The average net revenue per container in market \( i-j \) is \( R_{ij} \). The model would be as follows.
Objective is to maximize net revenue per route cycle, or:

\[
\text{Max } R_{12} \times x_{12} + R_{23} \times x_{23} + R_{31} \times x_{31} + R_{21} \times x_{21} \\
+ R_{32} \times x_{32} + R_{13} \times x_{13}
\]

Subject to ship capacity constraints on each route link and maximum demand, or:

\[
\begin{align*}
x_{12} + x_{13} + x_{32} & \leq \text{Ship capacity on route link 1-2} \\
x_{23} + x_{21} + x_{13} & \leq \text{Ship capacity on route link 2-3} \\
x_{31} + x_{32} + x_{21} & \leq \text{Ship capacity on route link 3-1}
\end{align*}
\]

\[
x_{ij} \leq \text{Maximum demand in O-D market } i-j
\]

\[
x_{ij} \geq 0 \text{ (demand not less than zero)}
\]

If the ocean liner wants to reserve a certain amount of space for an O-D market \(i-j\) (e.g. for their core business or best customers), an additional constraint such as \(x_{ij} \geq\) (reserved space) can easily be added.

The outcome of the model would be the number of containers to carry in each market. The results could help decide whether a market should be served at all, e.g. if \(x_{ij}\) is zero or close to zero. Serving too many markets is complicated and unfeasible strategically because the company’s resources and management’s attention may be spread too thin. Here the model helps management focus on the most important ones.
The model can also be used to decide which markets to serve over peak periods, or in times of increasing demand when the demand on one or more links of the route exceeds the ship capacity allocated. The ocean liner may then choose to buy a new ship, assign another ship to the route, or continue using the current one and only carry the most profitable cargo. The decision model can assist the firm in taking the right decision.

The model also demonstrates very well the concept of route or network displacement cost. If containers with little revenues are loaded in one port to be transferred to a third port, they may displace higher revenue containers that might have been loaded in the second port, but could not because of ship capacity constraints.

This model can be run with all available ship sizes and the optimum ship can then be chosen. The increased cost of operating a larger ship should of course be weighed against the increased revenues from serving more markets. In Chapter 4.4, an extended version of the above model is applied to a real world fleet assignment problem. This model is also built into FLEET IMPACT.

As transport markets around the world become more deregulated the number of servable markets on a route increases as shown previously, i.e. if n port visits are made, the number of servable O-D markets is n * (n - 1). Previously, the firm may have served only a few of those markets because of regulation constraints. Analyzing those markets would
have been an easy job with a simple spreadsheet model but as the number of servable markets skyrockets under deregulation it becomes very difficult to analyze them in order to optimize the objectives of the company. An example of such a complicated scenario would be an ocean liner operating from an island midway between two trade blocs such as North America and Europe. Even if it has only two routes, or one to each continent, and each route has seven port calls plus one on the island (port calls \( n = 15 \)), the number of servable markets becomes \( n \times (n - 1) \) or 210. In such cases, an operations research model such as the one introduced previously will be indispensable as a planning tool, and any company ignoring the potential of such mathematical methods may face reduced revenues and market share.

2.3.2. CRITICISM OF OPERATIONS RESEARCH METHODS

The main criticism of mathematical models is that they do not represent the real world very well. It can be argued that the more complex the model becomes, the closer it approaches the real world. But increasing complexity usually means less workability, so solutions are usually compromised ones. Following are other weaknesses in implementing Operations Research (O.R.) methods.

O.R. is not always understood by decision-makers, who are at the highest levels of the company. They are often heavily involved in strategy, but not the details of operations which O.R. is all about. Their education seldom covers this field, which only in the last two
decades has been introduced into the general curricula of universities. Decision-makers usually will want to avoid uncertainties and the unknown and will rather stick to known empirical methods with weaknesses and strengths that they understand and can relate to other important intangible factors such as customer service and strategy. If they do not understand the models, the decision-making is effectively moved down to their computers and O.R. experts who have no experience or permission to take decisions that often involve large amounts of shareholders' money. That is what top-management is there for.

O.R. models require an objective function. It is not always given what a company's objective is. Is it to maximize profits, or revenues, or market share, or all of them, etc. and over what time frame, and what are the constraints? A company may want to increase market share for a while and then settle down and make a profit. Those are two sometimes contradictory objectives. In addition, customers may want to minimize their logistics costs or maximize their logistics performance and this may contradict the ocean liner's objective, if incorrectly defined. Also, each manager within the firm may have his own objective, e.g. marketing wants maximum market share, finance wants maximum revenues, operations want minimum cost, etc. The objective would be based on his own incentives, and if pursued, might lead to a suboptimization of the firm's overall objective(s). The math model would then include the objective of the "strongest" manager involved.

Still another example might be a dominating company operating in an unregulated environment, which may want to provide services to
unprofitable ports and limit its rates somewhat, so as to avoid regulation. Obviously it is difficult to determine the "correct" objective function(s) in cases such as these.

O.R. models seldom improve efficiency drastically. In airline fleet planning it has been estimated that the potential for savings is 10%. Only half of that has yet been achieved, mainly because the mathematical theory and computer power needed to realize the savings fully does not yet exist. In many instances a 10% difference in fleet operating costs is considered insignificant when other factors, such as fleet flexibility and strategy enter the picture.

The same can be said of O.R. as of NPV analysis, which is that O.R. is more important when planning for a well established route with stable, predictable demand, but less so for new and risky routes.

It is not surprising then that many decision-makers, even those who are familiar with O.R. methods, are not interested in them because there exist uncertainties that can easily overwhelm the efficiency gain from using O.R.
2.3.3. SCHEDULE RELIABILITY ANALYSIS WITH GERT MODELING

GERT, or *Graphical Evaluation and Review Technique*, is a powerful tool for analyzing transport networks. When applied to fleet planning it can show how reliable the schedule is, how well equipment and other resources are utilized, and where potential route bottlenecks may be.

One example of its use is to determine the schedule reliability in a certain O-D market. Here the market can be served by more than one ship, such as in feeder service. Any route that affects the path of the cargo is divided into a manageable and practical number of operating units, and each is then analyzed to get the statistical characteristics for the operation/event, such as how likely it is to happen, type of distribution, and its average and standard deviation. An example could be a ship serving two ports, that of Reykjavik (REK) and Boston (BOS).

Sailing time from REK is operation number one. It could be normally distributed with average 170 hours and standard deviation of 20 hours. Sailing happens with probability 0.9 since bad weather (operation/event nr. 2) can prevent the sailing with likelihood 0.1. If there is bad weather, it delays departure by 12 hours, with a normal distribution and a standard deviation of 3 hours.

Next is to get the ship to the berth in BOS. The likelihood of that happening is 0.8 since the ship might have to wait for a berth
(operation 3) with chance or conditional probability 0.2. If it has to wait, the wait time will be exponentially distributed with an average wait time of 15 hours.

The fourth operation is to have the ship unloaded and loaded. The time it takes is normally distributed with average 20 hours, and standard deviation of 7 hours. Its conditional probability is 1.0 since the event always happens.

Finally the ship has to get back to REK. This is assumed deterministic at 170 hours. Another assumption is that there is enough buffer time in REK to prevent departure delays, other than weather, to Boston.

Each of the above operations is assigned an equivalent function $W_{i,j}(s)$ for the link $i$-$j$ which denotes the operation. The equivalent function is defined as:

$$W_{i,j}(s) = P_{i,j} \cdot M_{i,j}(s)$$

(2-4)

where $P_{i,j}$ is the conditional probability of operation $i$-$j$ (it would be 0.2 for operation 2 above), and $M_{i,j}(s)$ is the moment generating function of the distribution of the time required to perform operation $i$-$j$. $M_{i,j}(s)$ for a normal distribution is $\text{EXP}[s \cdot m + 0.5 s^2 \sigma^2]$ where $m$ is the average and $\sigma$ is the standard deviation. The moment generating functions for various distributions can be found from tables.
The equivalent function between any two points i and j can now be found. This is done with the following formula, utilizing Mason's reduction technique for networks, which is well known in control engineering:

\[ \mathcal{W}_{i,j}(s) = \Sigma_a \left[ G_a \ast \delta_a / \delta \right] \]  \hspace{1cm} (2-5)

where:

- \( a \) is over all paths from i to j
- \( G_a \) = equivalent function of path a going from node i to j
- \( \delta = \) graph determinant
  \[ \delta = 1 - \Sigma_i L_i + \Sigma_i \Sigma_j L_i L_j - \Sigma_i \Sigma_j \Sigma_k L_i L_j L_k + \ldots \]
  \( i \neq j \)
  \( i \neq j \)
  \( j \neq k \)
  \( i \neq k \)
- \( \Sigma_i L_i = \) sum of equivalent functions of loops i (i = 1, 2,...)
- \( \Sigma_i \Sigma_j L_i L_j = \) sum of products of pairs of equivalent functions of nontouching loops
- \( \Sigma_i \Sigma_j \Sigma_k L_i L_j L_k = \) sum of products of triplets of equivalent functions of nontouching loops
- \( \delta_a = \) the graph determinant in which the equivalent function of loops that touch path a are made equal to zero

A loop is defined as a path that comes back to the original node without touching another node more than once.
After the above equivalent function has been solved for, the expected time it takes to complete operation \( i-j \) (e.g. get from port \( i \) to port \( j \) on some route) can be found by differentiating \( W_{i,j}(s) \) with respect to \( s \) and setting \( s \) to zero, and then dividing by \( W_{i,j}(0) \). The variance also follows. In formula form this becomes:

\[
E_{i,j} = \frac{(d/ds) W_{i,j}(s)}{W_{i,j}(0)}, \quad s = 0
\]  

\[
\sigma^2_{i,j} = \frac{(d^2/ds^2) W_{i,j}(s)}{W_{i,j}(0)} - E^2_{i,j}, \quad s = 0
\]  

When gathering data for the above analysis, each operation has to be assigned a distribution. The fit of the distribution to real data can be verified with a chi-square statistical test, and the average and standard deviation of the data can easily be calculated.

The example introduced at the beginning of this chapter will now be analyzed in order to find out the expected time and variance of shipping cargo from Reykjavik to Boston, or from point 1 to point 3.

First, a table of operations, such as the one that follows, is built. In it each operation is described, what path it has, the operation's conditional probability, type of distribution, and finally the average time and standard deviation, if appropriate.
Table 2-1. Transport network characteristics

<table>
<thead>
<tr>
<th>Path</th>
<th>Operation</th>
<th>Probab.</th>
<th>Distribution</th>
<th>Mean, σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Weather delay, REK</td>
<td>0.1</td>
<td>Normal</td>
<td>12,3 hrs</td>
</tr>
<tr>
<td>1-2</td>
<td>Sail to BOS</td>
<td>0.9</td>
<td>Normal</td>
<td>170,20</td>
</tr>
<tr>
<td>2-2</td>
<td>Wait for berth, BOS</td>
<td>0.2</td>
<td>Exponential</td>
<td>15</td>
</tr>
<tr>
<td>2-3</td>
<td>Load/unload, BOS</td>
<td>1.0</td>
<td>Normal</td>
<td>20,7</td>
</tr>
<tr>
<td>3-4</td>
<td>Sail to REK</td>
<td>1.0</td>
<td>Deterministic</td>
<td>170</td>
</tr>
</tbody>
</table>

For each of the distributions, a moment generating function (MGF) is chosen. They can be found in tables (see Ref. 8). For the normal distribution the MGF is:

\[ \exp[s \cdot m + 0.5 s^2 \sigma^2] \]

Here \( m \) and \( \sigma \) are the average and standard deviation of the distribution, respectively. For the exponential distribution the MGF is:

\[ (1 - s/a)^{-1} \]

where \( 1/a \) is the average of the distribution. The equivalent functions for each link would therefore be (see Table 2-1 and formula (2-4)):

\[ W_{1,1}(s) = \exp[s \cdot 12 + 0.5 s^2 3^2] \]
\[ W_{1,2}(s) = \exp[s \cdot 170 + 0.5 s^2 20^2] \]
\[ W_{2,2}(s) = [1 - 15 \, s]^{-1} \]
\[ W_{2,3}(s) = \exp[s \times 20 + 0.5 \, s^2 \, 7^2] \]

The next step is to calculate \( G_a, \delta_a \) and \( \delta \). Since there is only one path from 1 to 3 \((a = 1)\), \( \delta_1 = 1 \), and:

\[ G_1 = W_{1,2}(s) \times W_{2,3}(s) \]

\[ \delta = 1 - W_{1,1}(s) - W_{2,2}(s) + W_{1,1}(s) \times W_{2,2}(s) \]

The equivalent function for the path between points 1 and 3 is therefore:

\[ W_{1,3}(s) = \frac{G_1}{\delta} \]

All that is left is to use formulas (2-6) and (2-7) to get the expected time, \( E_{1,3} \), and variance, \( \sigma_{1,3}^2 \), of going from REK to BOS. These two numbers reveal how reliable the schedule is, whether improvements are needed, and where. Any number of port visits, routes, and operations/events can be added to this analysis. Software for solving the above is readily available, making it an automated process.

The GERT technique can be used to analyze an operation across routes, such as in feeder operations. Any O-D market the ocean liner serves can be analyzed. Multiple routes would then be included in the moment generating function since they all affect the reliability of
service in the previously mentioned O-D market. It is important to assess the reliability of service between certain ports since they may be more important than other ports in the transport network.
3. **FLEET IMPACT**: OPTIMIZATION SOFTWARE FOR FLEET PLANNING

3.1. SOFTWARE DESCRIPTION

FLEET IMPACT is a computer program designed to aid in fleet planning for ocean transport. It was developed as part of this thesis and incorporates some of the ideas and measures introduced in it. It can be run on any PC-DOS computer by simply entering IMPACT at the DOS prompt. For the software to function adequately, the files IMPACT.EXE, HELP.DAT and VIDEO.CFG must all be present and in the same directory.

The program is designed to maximize freight revenues over a route, given capacity constraints. It does so by solving the LP model, introduced in Ch. 2.3.1. and built into FLEET IMPACT, by applying the Simplex method. The program is also designed to analyze the effects of various fleet plans on customers' logistics costs. The logistics include in-transit inventory expenses and losses due to the perishability of cargo. In addition to the above, FLEET IMPACT analyzes operating factors such as Available Container (or Ton) miles (ACMs or ATMs), Revenue Container (or Ton) miles (RCMs or RTMs) and load factors, both on a system wide and a per-link basis. These were introduced in Chapter 2.

FLEET IMPACT is a full-fledged, user-friendly program. It has two menus which can be seen on the following page. One is the main menu which handles data processing, the viewing and printing of output, and also includes help information.
MAIN MENU

0 Quit Fleet Impact
1 Input Sub-Menu
2 Run Fleet Impact
3 View Output
4 Print Output
5 View Any File
6 Help

INPUT SUBMENU

0 Exit to Main Menu
1 Route Properties
2 Origin-Destination Data
3 Port Call Names
4 Perishable Goods Data
5 Save Inputs to File
The other (sub-) menu is used to build the input file to be processed by the main menu. The user enters all relevant data into the program sub-menu which then prepares an input file, which contains all the input data. This input file is then processed later.

After the input file has been saved in the sub-menu, the user exits to the main menu where the input file is processed and an output file is created. An example of output is shown on page 72. This output is for the North America route of an ocean liner. That route is also analyzed with an LP model in Ch. 4.4. Part of the Route data and all of the Origin-Destination data come from Tables 4-1 and 4-2. The O-D data seen in Table 4-2 is realistic data. The route data is accurate.

The output file shows various operating and service quality factors. At the top of the output file, the input data is repeated for verification purposes. It is followed by the outcome of the optimization model. The LP table shows the available freight, or freight demand, and the amount of freight to carry in each O-D market in order to maximize freight revenues. In the last column, the spill is shown. Spill is the amount of freight that had to be rejected because of ship capacity constraints. In the example output file on page 72, the LP output table shows that to maximize net freight revenues, no containers should be carried in O-D markets 3-1 and 4-1, and only part of the freight in O-D market 7-1 (i.e. 140 TEUs) should be carried. These are the same results shown in Table 4-6 for a ship capacity of 290 TEUs.
The LP output table is then followed by system-wide output factors. These are ACMs (or ATMs if freight units are in Tons), RCDs (or RTDs), RCMs (or RTMs) and the Average Load Factor (ALF). The ALF is a weighted average of the link load factors with distance, or \[ \text{ALF} = \frac{\text{RCM}}{\text{ACM}} \] (or \[ \frac{\text{RTM}}{\text{ATM}} \] in case of Ton units). The same units are then shown for each link and O-D market, in table form.

Finally the output file shows results of a perishability analysis, both system wide, and in each O-D market. It can be viewed from inside the computer program and printed out.

All of the above outputs are based on the optimum solution from the LP model, and the numbers are on a per route-cycle basis.
FREIGHT DATA:

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Avail. Freight (TEUs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>58</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>33</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USNRF/ISREK</td>
<td>21</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>16</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>72</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNRF/CANAR</td>
<td>18</td>
</tr>
<tr>
<td>5 - 1</td>
<td>CANAR/ISREK</td>
<td>305</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>62</td>
</tr>
</tbody>
</table>

************************** OUTPUT DATA **************************

LINEAR PROGRAM (LP) OUTPUTS:

Total spill at LP optimum is: 258 TEUs
Total net freight revenues at LP optimum are: 568723

LP RESULTS. FREIGHT TO CARRY IN EACH O-D (TEUs):

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Avail. Frt.</th>
<th>To carry</th>
<th>Spill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>58</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>33</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>21</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>16</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>72</td>
<td>0</td>
<td>72</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNRF/CANAR</td>
<td>12</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>88</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>62</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>305</td>
<td>140</td>
<td>165</td>
</tr>
</tbody>
</table>
SYSTEM-WIDE OUTPUTS:

Available Container-Miles (ACMs): 1675620
Revenue Container-Days (RCDs): 2879
Revenue Container-Miles (RCMs): 867599
Average Load Factor (ALF): 51.8%

ROUTE LINK OUTPUTS:

<table>
<thead>
<tr>
<th>Link#</th>
<th>Port pair</th>
<th>RCMs</th>
<th>RCDs</th>
<th>LF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ISREK-CANAR</td>
<td>101616</td>
<td>327</td>
<td>20.0</td>
</tr>
<tr>
<td>2</td>
<td>CANAR-USBOS</td>
<td>54873</td>
<td>201</td>
<td>31.4</td>
</tr>
<tr>
<td>3</td>
<td>USBOS-USNYC</td>
<td>44726</td>
<td>165</td>
<td>36.9</td>
</tr>
<tr>
<td>4</td>
<td>USNYC-USNRF</td>
<td>17812</td>
<td>61</td>
<td>21.0</td>
</tr>
<tr>
<td>5</td>
<td>USNRF-CAHAL</td>
<td>103448</td>
<td>310</td>
<td>46.2</td>
</tr>
<tr>
<td>6</td>
<td>CAHAL-CANAR</td>
<td>37044</td>
<td>172</td>
<td>67.6</td>
</tr>
<tr>
<td>7</td>
<td>CANAR-ISREK</td>
<td>508080</td>
<td>1643</td>
<td>100.0</td>
</tr>
</tbody>
</table>

REVENUE CONTAINER-DAYS (RCDs) BY O-D MARKET:

<table>
<thead>
<tr>
<th>O-D market</th>
<th>Origin/Dest.</th>
<th>RCDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>545</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR-USNRF</td>
<td>157</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>0</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>92</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>0</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNYC/CANAR</td>
<td>50</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>57</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>779</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>406</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>793</td>
</tr>
</tbody>
</table>
PERISHABLES DEPRECIATION ANALYSIS:

Deprec. per day: 2.0%
System-wide loss: 13.7%
Total Perishable Cargo: 41 TEUs

PERISHABLES VALUE DEPR. BY O-D MARKET:

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Perish. Carried</th>
<th>Depr. (% of value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>15.7</td>
<td>18.8</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>11.6</td>
<td>9.5</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNYC/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>14.0</td>
<td>11.3</td>
</tr>
</tbody>
</table>

*************** END OF FLEET IMPACT ***************
3.2. MANUAL FOR THE USE OF FLEET IMPACT

CONTENTS:

INPUT DATA: General information about inputs.
MAIN MENU COMMANDS: Explains commands in the Main Menu.
SUB-MENU COMMANDS: Explains commands in the Input Sub-Menu.
FILES AND EXAMPLES: Names of files necessary to run program.
THE OUTPUT FILE: Output file and output interpretation.
INPUT FILE FORMAT: Shows the format of the input file.

INPUT DATA:

- The route cycle always starts and ends at node point 1, and must be closed.

- Each port call gets its own node point, so if a ship visits the same port twice in the same route cycle, each visit gets different numbers and is therefore a different Origin-Destination (O-D) market (this is important when entering O-D data).

- The port calls must be numbered in the right order, that is, port call 1 gets node point nr. 1, port call 2 gets node point nr. 2, etc.

- Links are ordered the same way, that is, link 1 is always between node points 1 and 2, link 2 is between node points 2 and 3, etc., and in general, link i is between node points i and i+1. An exception is
the last link which is between the node point for the last port call and node point 1.

- Freight must be entered either in TEUs or Tons. Distances must be in miles, and voyage and port time in hours.

- All inputs must be entered before saving to an input file (see sub-menu command 5 'Save Inputs to File' below).

- If the program fails, the fault is probably in the input file. That file is created in the Input Sub-menu. The input file must have the format shown on page 88. The input file can be viewed with any text editor, or by running command 5 'View Any File' from the Main Menu. If the input file is faulty it can be corrected by reading it into a word processor/editor, changing the wrong data, saving it in text (ASCII) form, and running FLEET IMPACT again.
MAIN MENU COMMANDS:

0 Quit

Terminates the program and returns to the DOS prompt. Asks for confirmation first.

1 Input Sub-Menu

This gives access to the Input Sub-menu. There, an input file can be created. This is usually the first step taken when using the program. It is highly recommended that input files be made this way instead of with an Editor.

2 Run Fleet Impact

Here the main processor is run. To do so, an input file has to exist. It can (should) be created in the Input Sub-Menu.

First the program asks for an input file. If the program fails at this stage, the cause is probably a bad input file.

If it exists, the program asks for an output file in which to store the processed data (i.e. FLEET IMPACT output). If the input file's name was chosen as ECoast.IN, the output file might be called ECoast.OUT. After entering the output file name, the program processes the input data and returns to Main Menu. At this stage the output can be viewed by choosing the View Output command which is discussed next.
3 View Output

This command will show the output from the program. In this mode the output can be browsed by pressing PgUp and PgDn on the keyboard. To return to Main Menu, press the Esc key on the keyboard.

4 Print Output

This command will print the most recent output from Main Menu command 2, ‘Run Fleet Impact’. It will only work if data has been processed. A printer must be connected to the computer at port LPT1, in order to print out. The computer then asks for verification.

5 View Any File

This can be used to view any file on the screen. The name of the file being viewed will appear at the top of the screen. Browse it by using PgUp and PgDn and use the Esc key to return to Main Menu.

6 Help

Displays ‘Help for Fleet Impact’ information.
SUB-MENU COMMANDS:

0 Exit to Main Menu

Self-explanatory. Exiting to Main Menu will not erase data that has been input in other parts of the sub-menu, as long as the user returns to the sub-menu without running command 2, 'Run Fleet Impact'.

1 Route Properties

First the program will ask for the route name. This is not a file name and will only be used to identify this particular route or run, e.g. if two inputs are processed, each with different demand patterns, but same route properties, the user could use separate names. The route name appears at the top of the output file, under the heading.

Next, the user will be asked to choose TEUs (press C on keyboard, C stands for Containers) or Tons (press T) as the freight units. It is important to be consistent and not mix them together.

The ship's capacity must then be entered. After that the program asks for the number of route links (must be fewer than thirty-one and more than two). A link is between each port pair.

Following this comes the voyage time on each link, that is, how long, in hours, it takes to sail the distance on each link. This is the difference between the departure time in previous port, and arrival time at next port, not including unloading and loading time.
The port time in originating port is then entered. This is the average port stay in this port, given the freight amount loaded and unloaded in it. Port time in destination port follows.

The length of each link (distance between ports) is then entered. It should be in miles.

After entering the above information for each and every link, the program returns to the sub-menu.

2 Origin-Destination Data

This is the freight input data. First the freight unit type should be entered (C or T).

Then enter the number of Origin-Destination markets. Cargo going from Boston to Norfolk would be one O-D market with (O)igin in Boston and (D)estination in Norfolk. Cargo going from Norfolk to Boston would be a different O-D market.

Next the amount of freight to transport between the origin and the destination should be input, in the appropriate units, of course.

Following that, the program asks for the average net freight revenue per unit of freight (TEU or Ton) for this O-D market.
Finally, the freight path must be entered. The program first asks for the originating node of the freight. If Boston has been designated node 3 in a route, New York has node 4, and Norfolk has node 5, the numbers 3, 4 and 5 would be entered for the cargo in the O-D market Boston-Norfolk, since this is the path of the freight going from Boston to Norfolk (it goes through New York). To stop the path input, the user must enter zero. Freight path entry is repeated for all O-D markets served by the route. The program then returns to the input submenu.

3 Port Call Names

First the program asks for the number of nodes in the route. Then it asks for the name of the port at node 1. Here an abbreviation such as USNYC should be used. It must be less than 6 letters. This is repeated for every node. Note that since two or more nodes may have the same port name, the port name may have to be entered more than once.

4 Perishable Goods Data

Here the perishability properties of the cargo is entered. First comes the percent value depreciation of the cargo. This is on a per-day basis. If no perishability analysis is wanted, a zero can be entered.

Next the percent of perishable cargo of the total cargo in each O-D market is entered. This is repeated for all O-D markets. Again, if no perishability analysis is wanted, a zero can be entered for every O-D market. The program then returns to Input Sub-Menu. At this stage the user should save the data to a file using the following command.
5 Save Inputs to File

Before running this command, all previous commands in the Input Sub-menu must have been run. In other words, all the data must be entered, e.g. if the user does not want to do Perishable Goods analysis (command 4 in sub-menu) he/she must still enter some 'dummy' data, such as '0', for each query in that command.

To remember what sub-menu inputs have been entered, the sub-menu command for each (e.g. '1 Route Properties') changes from white to gray after input. After saving to output file, or leaving to the main menu, the sub-menu commands become white again. This does not erase any inputs though. When the command is run, the program asks for the name of a file to store the input data. This data includes all the data entered in the Input Sub-Menu. An example file name could be ECoast.IN. After that it returns to the sub-menu. At this stage, the user may quit in the program since no data will be lost, or may wish to process the data. If so, the user must exit to the main menu and run command 2, 'Run Fleet Impact' which is explained previously.
FILES AND EXAMPLES:

The files necessary to run the program are Impact.EXE (main program), Help.DAT (run-time help information), and Video.CFG.

Example input files are included on the disk. These are files NAMMAX.IN and NAMAVER.IN. They can be processed immediately after program start-up. To do so, choose command 2 ‘Run Fleet Impact’, and when prompted for the input file names, enter either of them. When prompted for an output file name, enter any convenient name.

THE OUTPUT FILE:

At the top of the output file is the header, followed by the time and date. This identifies when the input file was processed into an output file. Following that are the route name, and the name of the input file used to create this particular output, along with the file that stores this output.

The next two tables repeat the inputs to the program for verification purposes.

Following them are the outputs from the FLEET IMPACT main processor. These are outputs from the LP optimization, system wide outputs, and outputs per-link and per O-D market, followed by the perishability analysis, system-wide, and per O-D market.
INTERPRETATION:

The Linear Programming (LP) optimization output shows what O-D markets should be served, and to what degree, so as to maximize net freight revenues. This information is needed if the ship capacity is exceeded on any route link. The LP model minimizes the network displacement cost, discussed in Ch. 2.3.1.

Revenue Container Days (RCDs or RTDs) are a measure of the in-transit inventory expenses for the ocean liner's customers. A route with a high system-wide RCD will have high logistics costs, and worse service. A route with a system-wide RCD number of 5000 would on average have twice as many containers in transit as a route with RCD = 2500, provided the route cycle time is the same. These numbers along with others introduced below can be used to analyze the effect of adding or cancelling a port call to a route, or rearranging port calls. Note that in the output from FLEET IMPACT, RCDs are calculated by including the voyage time, the whole port time in each through-port, i.e. where freight passes through, and half the port time at freight origin and destination.

RCDs per O-D market help determine what markets are most important, and therefore need more direct, or faster service. This helps a fleet planner decide in what order ports should be visited. A market with many containers going a short distance may be less important logistics-wise than a market with fewer containers going a long distance.
Perishables analysis system-wide says how much of the cargo value is lost per route-cycle. This is to be minimized, subject to each O-D market not having too much losses, or depreciation. This can also be used to see if a perishables O-D market should be served at all.

The table that shows losses per O-D market helps to reach the above goal. The system wide loss can be minimized while the loss in each O-D market is monitored to avoid too much loss.

The perishability analysis can also be used when assessing the feasibility of transporting a new type of perishable product on a particular route, possibly having to choose between various destination markets with varying prices, since a market with lower prices might be a better choice if the product gets there in better shape. The ocean liner does not sell the product, but if it thinks about its customer’s needs it may get more market share and revenues. Another example would be to see the difference weather has on a perishable product, e.g. in the summertime fresh fish will depreciate faster than in the winter. If fresh fish exporters are important customers of the ocean liner, it might want to vary its route plan by season to account for this.
INPUT FILE FORMAT:

On the following page is an example of an input file. All the appropriate data must be input if FLEET IMPACT is to work properly.

This file is on the accompanying disk under the file name NAmMax.IN (Route North America, with Maximum demand). Comments in parenthesis {..} are NOT supposed to be part of the input file.
The route starts at port ISREK and visits port CANAR (CANada, ARgentia) twice (see Table 4-1 for port names). The route path is ISREK-CANAR-USBOS-USNYC-USNRF-CAHAL-CANAR-ISREK. These have node points 1-2-3-4-5-6-7-1. Note that node points 2 and 7 are the same port (CANAR), but different port calls and different O-D markets, hence the different numbers. Also note that when port names are entered, the first port name, in this case ISREK, should not be entered at the end.

There should not be any empty lines in the input file. The empty spaces in lines 7, 16 and 17 of the file are only there because of the comments.
Example of input file for FLEET IMPACT:

INPUT  { A control string for internal use }
NAmerica_Max { Name of route or program run }
TEU   { Units of freight ('TEU' or 'TON', but not 'TEUs' or TONs' }
290   { Ship capacity in unit of choice }
7    { Nr. of route links }
     1  2  117  24  13  1752 { 1st node pt, 2nd, Voy. time, 1st port time, 2nd port time, Distance between port pair }
     2  3  40  13  13  603
     3  4  28  13  5  418
     4  5  19  5  5  292
     5  6  52  5  2  772
     6  7  13  2  14  189
     7  1  117  14  24  1752

10    { Nr. of O-D markets }
     58  1650 1  2  3  4 { Freight in O-D market 1, average net freight revenues per cargo unit, (goes from node 1 to node 4 through nodes 2 and 3)=path of freight }
     33  291  2  3  4  5 { Freight in O-D mkt. 2, etc }
     21  1230  3  4  5  6  7  1
     16  434  3  4  5  6  7
     72  815  4  5  6  7  1
     12  620  4  5  6  7
     18  540  5  6  7
     88  1397  5  6  7  1
     62  1980  6  7  1
     305  1383  7  1

7    { Nr. of port calls per route cycle }
ISREK { Name of port visited first }
CANAR { Name of port visited second }
USBOS { Name of port visited third, etc. }
USNYC
USNRF
CAHAL
CANAR { If a port is visited twice, its name appears twice, etc. }
2    { Percent depreciation per day of perishable freight }
27   { Percent of total freight in O-D mkt 1 that is perishable }
35   { Percent of total frt. in O-D mkt 2 that is perishable, etc. }
15
0
11
0
0
0
0
10
4. FLEET PLANNING FOR AN EXISTING OCEAN LINER

4.1. ABOUT THE OCEAN LINER

The ocean liner firm discussed here is based in Reykjavik, Iceland. It was founded in 1914, as the first Icelandic shipping company. The company’s prime mission is to run profitable transport services to and from Iceland, within Iceland, and those transport services abroad that will strengthen its primary services.

Its main routes are five. These are North American Services, UK and Eurocontinental, Scandinavian Services, Baltic, and finally, Icelandic Coastal Services.

The ocean liner is the largest such firm in the country. In 1991 it had operating revenues of 105 million dollars, made on assets worth 130 million dollars, with a return on equity of 10%, making it one of the 10 largest enterprises in the country. It has had consistent profits from 1986 to date, except for 1992 losses due to a local recession. Since 1984 its freight rates have gone down by approx. 38% in real terms. The amount of cargo carried by the firm in 1991 was 993 thousand tons, of which 49% was import, 39% export, with the remainder being international and coastal cargo. The company carries around 65% of all oceangoing trade to and from the country, excluding transport of fuel oils and aluminum which are carried by specialized foreign vessels.
The success of the company has come mainly by streamlining operations in their main terminal, and by reducing the number of ships and port turnaround time, and increasing their size and speed. None of this would have been possible without the introduction of containers in the company's operations. Chart 4-1 shows the trend in containerization from 1981 to 1991. Chart 4-2 shows productivity trends for main terminal workers from 1988 to 1992. In this period a bonus system was implemented in the main terminal after union negotiations. The chart shows that the productivity in TEUs per man-hour increased by 62% between 1988 and 1992. Over the same period the container flow only increased by 12%, so labor productivity indeed did increase. Total terminal wage costs per TEU, including bonus, also went down considerably in the period.

Because of this success, which is reflected in lower freight rates and costs, and improved profits and market share, the competitive pressure on other carriers has increased. As a result, the only state owned ocean liner ceased operations in 1992.

Despite all of this streamlining in the company's operations, its management believes that their fleet planning methods do not result in an optimum fleet size. This thesis introduces new methods and concepts that may be helpful in understanding and designing better fleet plans. Some of these methods are built into a computer program called FLEET IMPACT, that was developed as part of this thesis.
Chart 4-1

Main Terminal Container Flow

Chart 4-2

Main Terminal Productivity Trend

<table>
<thead>
<tr>
<th>Year</th>
<th>Scaled TEUs/man-hour, 1988=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>'88</td>
<td>1.00</td>
</tr>
<tr>
<td>'89</td>
<td>1.13</td>
</tr>
<tr>
<td>'90</td>
<td>1.35</td>
</tr>
<tr>
<td>'91</td>
<td>1.64</td>
</tr>
<tr>
<td>'92</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Scaled TEU/man-hour ➔ Container Flow
4.2. CURRENT METHODS FOR FLEET PLANNING

The ocean liner does a fleet planning study as follows.

A committee of four managing directors is formed. They are directors of the following departments: Department of Liner Services, Department of International Services, Department of Export Services, and a staff member of the Land Operations department.

The committee defines the problem with the current fleet in writing. These may be inadequate capacity problems, scheduling problems, e.g. schedules too tight, and service quality problems such as inadequate frequency of service to certain ports.

Next the committee sets its goals in writing. They are to solve the problems above, and in addition there may be other goals, such as to maintain the flexibility of the current fleet.

The company's main markets are then defined for the time horizon chosen, which is five years. The fleet plan must be able to serve these markets through that period.

Capacity assumptions are then made for export and import for each market, or port pair. They are based on marketing and economic analysis. A demand prediction is then made about future trends in freight transport. This is done both on an aggregate, or top-down, and detailed,
or bottom-up basis, depending on whether the market is a stable market, or a new and/or dynamic market.

Next, changes in number of port calls and ship size is studied. This is only done if cargo can be shipped to other ports. This means that demand assumptions are the same.

Numerous fleet plans are then studied, but after a closer look and simple calculations, part of those plans are eliminated as options, and the remainder is then studied in further detail.

Each fleet plan is set up with costs, and a list of pros and cons. No revenue analysis is done. One main criteria is to minimize the NPV of costs, subject to service standards and fleet flexibility. The main costs used are fleet operating costs, which include insurance, fuel expenditures, and daily operating costs. Other costs are port tariffs and "differential" costs. These differential costs are the cost differences between the current fleet plan and the proposed ones. They include changes in feeder costs (if ports are excluded permanently from the current plan, containers must be transported to other ports), container depreciation cost changes, and changes in stevedoring costs when port calls are excluded permanently. The costs used in this paragraph are estimated using some costs from current operations and other from estimating operating costs of ships available in the market.

Finally, the "best" fleet plan is chosen and implemented.
4.3. IMPROVEMENTS TO CURRENT METHODS

There are many possible areas for improvement in the ocean liner's procedures and methods of fleet planning. These include freight data handling, quality of service standards, customer logistics analysis, and more.

The first to mention is the handling of freight data. There is no statistical handling of past data, even simple numbers such as the standard deviation of freight demand are not calculated. If the standard deviation of the data is not known, it becomes hard to define the important quality of service factor called space availability (see Chapter 1.4.2). Currently the ocean liner says that it should satisfy all demand, but that is not a well defined service standard, and is actually not achievable.

Another weakness in data handling relates to capacity planning. A few peak weeks are taken, averaged out and then increased arbitrarily by 16%, to account for freight increases of 3% per year for a planning horizon of five years. This gives a reasonable approximation for future demand, but the planning method is partly based on constrained demand. Constrained demand is the amount of cargo that was actually carried on those trips, but not the amount of cargo space needed for those particular trips, since some of those trips were full and cargo was delayed or had to be turned away. The fleet capacity must be designed with demand freight data, or unconstrained demand in mind, and not
carried freight data (constrained demand). It is easy to change constrained demand to unconstrained using the methods introduced in Chapter 1.4.2. If predicted demand increases are wrong they should lead to either increasing excess capacity if the demand increase is overestimated, or increasing undercapacity if underestimated. If constrained data is used with a correct prediction of demand increases, it would lead to chronic undercapacity of a relatively fixed amount, which is a problem on most of the company's routes. In the future it would be better to carry a list of rejected containers, that is, of those containers that had to wait for the next trip, or were sent through other channels because there was no space on board. Rejected plus carried containers, avoiding double-counting, of course, could then be used as unconstrained demand.

There is no use of mathematical modeling in the ocean liner's fleet planning. A mathematical model can be helpful in fleet planning, and can give good insight into the dynamics and economics of operations. To build a mathematical model of operations, their details must be carefully mapped. Such mapping can be an important learning experience for those involved, and may aid in future decision-making. A mathematical optimization model such as that built into FLEET IMPACT can be an important part of fleet planning.

It is important to do an analysis on revenue and cost data to see how much more it costs to have ships that are slightly too large, with less revenue losses since no cargo is turned away, and how much is saved
by having ships that are slightly too small, with more revenue losses and worse service since cargo is delayed or turned away. The idea is to arrive at an optimum size. This would help define the space availability factor mentioned previously. Mathematical modeling can be helpful in the above.

There are improvements to be made in the area of logistics. The ocean liner emphasizes minimizing the cost of fleet operations instead of maximizing the performance of the fleet as part of a logistics channel. Transport factors that influence the logistics costs of customers are reliability of service, which affect safety stock, and choice of mode, and also trip time, including terminal and handling time which affect in-transit inventory, perishability, and loss and damage. Here, analysis of the commodities transported is necessary, with the goal of optimizing the fleet’s performance. By finding out how valueable trip time reductions are to customers, service could be improved at a cost, which would then be transferred to the customer in the form of higher freight rates, provided that the operating environment remains unregulated. FLEET IMPACT is ideal for this kind of analysis.

When doing their Net Present Value analysis of their fleet plan, all relevant costs seem to be included, but not the revenues. The assumption seems to be that revenues will remain the same, i.e. that no freight rate changes are possible because of changes in service. This may be a weakness because rate increases are possible if improvements,
such as those mentioned in the previous paragraph are made. And sensitivity analysis of revenues difficult without revenue estimates.

Few measures of service and the efficiency of operations are done in the ocean liner's fleet study. Measures, such as Revenue Container-Days (RCDs), the container share gap, and the unit revenue and cost measures, discussed in Chapter 2.2., can provide valuable insight into network performance, service quality, and efficiency. Not all of the measures mentioned are suitable for all types of operations as discussed in Chapter 2.2., but any fleet study will be improved if the appropriate measures are used. Too many measures can cause confusion so it is important to select the right ones.

The amount customers lose because of the perishability of fish is high, and justifies that it be included as a criteria in fleet planning. Of the 20 largest customers of the ocean liner, 15 are fish exporters. A careful analysis of how fish depreciates with time is necessary. Here, FLEET IMPACT can be useful. There are standard ways to predict the quality of fish, among other things by analyzing its temperature profile with time from the moment it is caught until it is auctioned. By studying many such exports, the trip time could then be correlated with the achieved auction price at the destination and in that way get an average devaluation of fish per trip day. The fleet's speed and/or schedule could then be designed with these factors in mind. A more convenient schedule could then be translated into higher rates for fish transport, since there would be returns to the customer in the form of
higher auction prices. This is one example of how minimizing the cost of operating the fleet is not the optimum, because customers seek logistics channels that have optimum performance.
4.4. AN OPERATIONS RESEARCH FLEET ASSIGNMENT MODEL

Following is a fleet planning model for an Icelandic ocean liner. The company carries containerized cargo from the port of Reykjavik to the East Coast of North America, and back. The company wants to know how much freight it should carry in each market under the following circumstances:

- In peak periods of the year when ship capacity on certain route links is inadequate

- In times of non-seasonal increasing demand when capacity is again inadequate, and a different ship must be assigned, or purchased, or cargo rejected

when the objective of the firm is to maximize contribution from this particular route. The output of the model should be the optimum number of containers to transport in each market, and the optimum ship size to use on the route. The optimization done in this chapter can also be done with FLEET IMPACT (see Ch. 3).

The input data

The input data used for these calculations is realistic, but different from the company's numbers for confidentiality reasons.
The inputs to the mathematical model are:

- average net revenues per container in each O-D market
- amount of freight demand in each market
- available ship capacity

The ocean liner makes a port call in each of five East Coast ports, and one port call in Iceland. The route is served bi-weekly by one ship. One of the East Coast ports is visited twice. There are a total of seven port calls. The effective number of O-D markets is therefore 30 \((n = 6, \text{ see formula (1-2), Ch. 1.4.1})\). Currently the firm is only serving ten of those, and does not expect any changes to that for the current planning horizon. The ports served, and their order is shown in the following table.

Table 4-1. Port calls on route North America

<table>
<thead>
<tr>
<th>Port number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reykjavik</td>
</tr>
<tr>
<td>2</td>
<td>Argentia (Canada)</td>
</tr>
<tr>
<td>3</td>
<td>Boston/Everett</td>
</tr>
<tr>
<td>4</td>
<td>New York City</td>
</tr>
<tr>
<td>5</td>
<td>Norfolk</td>
</tr>
<tr>
<td>6</td>
<td>Halifax</td>
</tr>
<tr>
<td>7</td>
<td>Argentia (again)</td>
</tr>
</tbody>
</table>
Table 4-2 shows the active O-D markets, the container traffic in each of them, and the average net revenues. Here, O-D market 2-5 means the market from Argentia to Norfolk (see Table 4-1). TEUs are the average and maximum number of containers carried per route cycle which takes two weeks. The maximum, which is the average of two peak periods in the market, occurs in March through May every year. It would be more accurate to use the standard deviation to define the space availability, that is the maximum space allocated to each market, but it is not available, so the maximum demand is used instead.

**Table 4-2. Bi-weekly freight data for route North America**

<table>
<thead>
<tr>
<th>O-D market i-j</th>
<th>TEUs (aver., max)</th>
<th>Net revenue ($/TEU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5</td>
<td>26, 33</td>
<td>291</td>
</tr>
<tr>
<td>1-4</td>
<td>46, 58</td>
<td>1650</td>
</tr>
<tr>
<td>3-7</td>
<td>11, 16</td>
<td>434</td>
</tr>
<tr>
<td>4-7</td>
<td>9, 12</td>
<td>620</td>
</tr>
<tr>
<td>5-7</td>
<td>14, 18</td>
<td>540</td>
</tr>
<tr>
<td>6-1</td>
<td>45, 62</td>
<td>1980</td>
</tr>
<tr>
<td>7-1</td>
<td>244,305</td>
<td>1383</td>
</tr>
<tr>
<td>3-1</td>
<td>15, 21</td>
<td>1230</td>
</tr>
<tr>
<td>4-1</td>
<td>55, 72</td>
<td>815</td>
</tr>
<tr>
<td>5-1</td>
<td>69, 88</td>
<td>1397</td>
</tr>
</tbody>
</table>
The mathematical model

The company’s objective is to maximize the route’s contribution to overhead. This is done by using an objective function that maximizes revenues per route cycle, and then, after the model has been run, the fixed cost of operating each ship size can be subtracted from those revenues. Here the realistic assumption is made that the operating cost of the ship is fixed, i.e. it does not vary with cargo amount except for the container depreciation and handling costs which are subtracted from the freight revenues to give the net revenues, shown in Table 4-2.

The decision variables for the model are the number of containers to carry in each market. These variables are called $x_{ij}$ where $x$ is the number of containers to carry from market $i$ to market $j$. The first group of constraints on the decision variables is that they cannot exceed the available freight amount (see TEUs per cycle in Table 4-2). The second group of constraints is that the amount of containers carried on each link can not exceed the ship capacity on that link. The ship capacities to use in the constraints parts of the model are 290, 370, 500, and 800 TEUs. These are the ship sizes currently available to the ocean liner. The daily operating costs of these ships are shown in Tables 4-3 and 4-4 (see "Cost" columns).

The mathematical model can now be put together as shown previously in Chapter 2.3.1. The following model uses the average numbers of demand
in the constraints. The objective function and the constraints have the form:

\[
\text{MAX } 291 \, x_{25} + 1650 \, x_{14} + 434 \, x_{37} + 620 \, x_{47} + 540 \, x_{57} \\
+ 1980 \, x_{61} + 1383 \, x_{71} + 1230 \, x_{31} + 815 \, x_{41} + 1397 \, x_{51}
\]

\[
\text{SUBJECT TO}
\]

\[
x_{14} \leq \text{Ship Capacity ! link 1-2};
\]

\[
x_{25} + x_{14} \leq \text{Ship Capacity ! link 2-3};
\]

\[
x_{25} + x_{14} + x_{37} + x_{31} \leq \text{Ship Capacity ! link 3-4};
\]

\[
x_{25} + x_{37} + x_{47} + x_{31} + x_{41} \leq \text{Ship Capacity ! link 4-5};
\]

\[
x_{37} + x_{47} + x_{57} + x_{51} + x_{31} + x_{41} \leq \text{Ship Capacity ! link 5-6};
\]

\[
x_{37} + x_{47} + x_{57} + x_{61} + x_{51} + x_{31} + x_{41} \leq \text{Ship Capacity ! link 6-7};
\]

\[
x_{61} + x_{51} + x_{71} + x_{31} + x_{41} \leq \text{Ship Capacity ! link 7-1};
\]

\[
x_{25} \leq 26 \! \text{ Average demand in market 2-5};
\]

\[
x_{14} \leq 46 \! \text{ etc.};
\]

\[
x_{37} \leq 11
\]

\[
x_{47} \leq 9
\]

\[
x_{57} \leq 14
\]

\[
x_{61} \leq 45
\]

\[
x_{71} \leq 244
\]

\[
x_{31} \leq 15
\]

\[
x_{41} \leq 55
\]

\[
x_{51} \leq 69
\]
The model was run with two demand numbers, average and maximum demand, and with the four ship sizes mentioned previously, and the inputs to, and outputs from the eight runs can be seen in full in Appendix A.

The output data

Following are Tables 4-3 and 4-4, that summarize the objective function outcome of the models, and Tables 4-5 and 4-6 that summarize the optimum amount of containers to carry in each market.

The revenues, costs and contribution in Tables 4-3 and 4-4 are on a per-route cycle basis, and their units are in thousands of dollars. The cost of operating the ships is the direct ship operating cost.

If the fleet planning was done for average demand (see Table 4-3), the optimum ship size would be 370 TEUs, or where the contribution to overhead is maximum. This is not the appropriate ship for peak seasons since it could not cover the peaks. If larger ships were used in low season the contribution numbers show how much is lost because of operating ships that are too large.

By using the maximum demand as the input data to the model, a more realistic outcome is seen (see Table 4-4). Here the optimum ship size would be 500 TEUs with the 750 TEU ship very close. The 290 and 370 TEU ships would now be infeasible because of the unacceptable rate of freight rejection, i.e. too much traffic is turned away or spilled, as shown in Tables 4-5 and 4-6.
Table 4-3. Summary with average demand

<table>
<thead>
<tr>
<th>Ship (TEUs)</th>
<th>Revenues ('000s $)</th>
<th>Cost ('000s $)</th>
<th>Contribution ('000s $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>530</td>
<td>83</td>
<td>447</td>
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<tr>
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<td>225</td>
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Table 4-4. Summary with maximum demand

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<th>Ship (TEUs)</th>
<th>Revenues ('000s $)</th>
<th>Cost ('000s $)</th>
<th>Contribution ('000s $)</th>
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<td>881</td>
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</table>
The number of containers to carry in each market so as to maximize revenues is shown in Tables 4-5 and 4-6. "ALL" means that all available demand should be satisfied. The first table shows the strategy for the average demand, and the second shows it for the maximum demand. At the bottom of each table the number of rejected containers is shown for each fleet plan. As can be seen, the spill is unacceptable for both demand assumptions for the 290 and 370 TEU ships. They are therefore unlikely candidates. Which of the two remaining ships is optimal depends on the firm's quality of service policy towards each market. Market 4-1, (New York to Reykjavik) which would have spill of 48 containers over the peak period if the 500 TEU ship was selected, is important, and therefore requires the 750 TEU ship, at least over the peak period. The reduction in contribution to overhead (see Table 4-4) of using the larger ship in the peak period would be relatively small, or sixteen thousand dollars per route cycle.
Table 4-5. TEUs to carry in each market with average demand

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<td>7-1</td>
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Spill (TEUs) 138 58 0 0
Table 4-6. TEUs to carry in each market with maximum demand

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Spill (TEUs) 258 178 48 0
5. CONCLUSION AND RECOMMENDATIONS

In previous chapters, many concepts and performance measures related to fleet planning have been introduced and discussed. Some of them are known but have not yet been generally accepted in the fleet planning studies of some ocean transport firms. Others are introduced here for the first time in an attempt to eliminate weaknesses in current fleet planning methods. A brief listing of what is introduced follows:

- The methodology of fleet studies
- The aggregate and detailed fleet planning methods
- The HHI measure of competition in a transport market
- The O-D market concept
- Economies of scope and scale in feeder service
- The frequency saturation concept
- Demand forecasting and data analysis
- Constrained and unconstrained data
- The importance of NPV analysis
- Customer logistics and fleet planning
- The network displacement cost concept
- The importance of understanding competing modes
- Production, efficiency and service quality measures
- Optimization methods and an example of application
- Mathematical models for schedule reliability analysis
The second half of the thesis then introduces a fleet planning method currently used at an ocean liner, along with new methods which may improve planning, using the concepts and performance measures introduced above. Many of these measures are built into FLEET IMPACT. The possible areas of improvement are summarized below.

Statistical handling of data could be improved. Without numbers such as the average and variance it is difficult to define certain service quality measures.

Capacity planning is partly based on constrained demand. This may lead to chronic undercapacity. Unconstrained demand should be used.

There is no use of mathematical modeling. Such modeling can improve decision-making and provide valuable insight into the operations and economics of the fleet. An optimization model is built into FLEET IMPACT (see Ch. 3).

There is no analysis of customer logistics costs. The firm might improve service at a cost, which would then be passed on to customers who would save in the form of lower logistics costs.

The NPV analysis is based on minimizing costs, revenues are not included. This makes analysis, such as that discussed in the previous paragraph, difficult.
Few measures of service and efficiency of operations are done in the fleet study. Having solid measures such as those introduced in Ch. 2.2. can improve service, and prevent mistakes in fleet planning. FLEET IMPACT can be used effectively to apply some of these measures.

Analysis of the perishability of fish is absent. Fifteen of the twenty largest customers of the ocean liner are fish exporters, and since the perishability losses can be significant as shown elsewhere, this is a weakness. FLEET IMPACT is ideal for the perishability analysis of freight over a route.

Scheduling is a problem as the company’s ships routinely go out of it. All operations related to the schedule could be analyzed with a method like GERT modeling, introduced in Chapter 2.3.3. The results can be used to pinpoint the problems that cause abnormal schedule delays.
6. REFERENCES

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   Course lecture notes at MIT, 1993.

2. Belobaba, P.P., Simpson, R.W.: Air Transportation Economics,
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7. Evans, J.R., Minieka, E.: Optimization Algorithms for
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8. Frankel, E.G.: Port Planning and Development,


APPENDIX A: LINEAR PROGRAMMING MODELS

This appendix includes the eight linear programming models discussed in Chapter 4.4. The first four models are run with average demand, and all four ship sizes. The remaining four models were run with maximum demand, and same ship sizes. The software package used to solve the problems was LINDO. The models are as follows:

Model 1. Average Demand with ship capacity 290 TEUs
Model 2. Average Demand with ship capacity 370 TEUs
Model 3. Average Demand with ship capacity 500 TEUs
Model 4. Average Demand with ship capacity 750 TEUs

Model 5. Maximum Demand with ship capacity 290 TEUs
Model 6. Maximum Demand with ship capacity 370 TEUs
Model 7. Maximum Demand with ship capacity 500 TEUs
Model 8. Maximum Demand with ship capacity 750 TEUs
MODEL 1. AVERAGE DEMAND WITH SHIP CAPACITY 290 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
    + 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 290 ! link 1-2;
x25 + x14 <= 290 ! link 2-3;
x25 + x14 + x37 + x31 <= 290 ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 290 ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 290
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 290
x61 + x51 + x71 + x31 + x41 <= 290
x25 <= 26 ! Average demand in market 2-5;
x14 <= 46 ! etc.;
x37 <= 11
x47 <= 9
x57 <= 14
x61 <= 45
x71 <= 244
x31 <= 15
x41 <= 55
x51 <= 69
END
LEAVE
LP OPTIMUM FOUND AT STEP 9

OBJECTIVE FUNCTION VALUE

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MODEL 2. AVERAGE DEMAND WITH SHIP CAPACITY 370 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
+ 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

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x25 + x14 <= 370  ! link 2-3;
x25 + x14 + x37 + x31 <= 370  ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 370  ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 370
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 370
x61 + x51 + x71 + x31 + x41 <= 370
x25 <= 26  ! Average demand in market 2-5;
x14 <= 46  ! etc.;
x37 <= 11
x47 <= 9
x57 <= 14
x61 <= 45
x71 <= 244
x31 <= 15
x41 <= 55
x51 <= 69
END
LEAVE
LP OPTIMUM FOUND AT STEP 9

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MODEL 3. AVERAGE DEMAND WITH SHIP CAPACITY 500 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
+ 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 500 ! link 1-2;
x25 + x14 <= 500 ! link 2-3;
x25 + x14 + x37 + x31 <= 500 ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 500 ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 500
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 500
x61 + x51 + x71 + x31 + x41 <= 500
x25 <= 26 ! Average demand in market 2-5;
x14 <= 46 ! etc.;
x37 <= 11
x47 <= 9
x57 <= 14
x61 <= 45
x71 <= 244
x31 <= 15
x41 <= 55
x51 <= 69
END
LEAVE
LP OPTIMUM FOUND AT STEP 10

OBJECTIVE FUNCTION VALUE

1) 687600.000

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NO. ITERATIONS= 10
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MODEL 4. AVERAGE DEMAND WITH SHIP CAPACITY 750 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
+ 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 750 ! link 1-2;
x25 + x14 <= 750 ! link 2-3;
x25 + x14 + x37 + x31 <= 750 ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 750 ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 750
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 750
x61 + x51 + x71 + x31 + x41 <= 750
x25 <= 26 ! Average demand in market 2-5;
x14 <= 46 ! etc.;
x37 <= 11
x47 <= 9
x57 <= 14
x61 <= 45
x71 <= 244
x31 <= 15
x41 <= 55
x51 <= 69
END
LEAVE
LP optimum found at step 10

Objective function value

1) 687600.000

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MODEL 5. MAXIMUM DEMAND WITH SHIP CAPACITY 290 TEUS

MAX 291 \(x_{25} + 1650 \ x_{14} + 434 \ x_{37} + 620 \ x_{47} + 540 \ x_{57}\)

\[+ 1980 \ x_{61} + 1383 \ x_{71} + 1230 \ x_{31} + 815 \ x_{41} + 1397 \ x_{51}\]

ST
\(x_{14} \leq 290 \) ! link 1-2;
\(x_{25} + x_{14} \leq 290 \) ! link 2-3;
\(x_{25} + x_{14} + x_{37} + x_{31} \leq 290 \) ! link 3-4;
\(x_{25} + x_{37} + x_{47} + x_{31} + x_{41} \leq 290 \) ! etc.;
\(x_{37} + x_{47} + x_{57} + x_{51} + x_{31} + x_{41} \leq 290\)
\(x_{37} + x_{47} + x_{57} + x_{61} + x_{51} + x_{31} + x_{41} \leq 290\)
\(x_{61} + x_{51} + x_{71} + x_{31} + x_{41} \leq 290\)
\(x_{25} \leq 33 \) ! Average demand in market 2-5;
\(x_{14} \leq 58 \) ! etc.;
\(x_{37} \leq 16\)
\(x_{47} \leq 12\)
\(x_{57} \leq 18\)
\(x_{61} \leq 62\)
\(x_{71} \leq 305\)
\(x_{31} \leq 21\)
\(x_{41} \leq 72\)
\(x_{51} \leq 88\)

END

LEAVE
LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

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MODEL 6. MAXIMUM DEMAND WITH SHIP CAPACITY 370 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57 
+ 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 370  ! link 1-2;
x25 + x14 <= 370  ! link 2-3;
x25 + x14 + x37 + x31 <= 370  ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 370  ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 370
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 370
x61 + x51 + x71 + x31 + x41 <= 370
x25 <= 33  ! Average demand in market 2-5;
x14 <= 58  ! etc.;
x37 <= 16
x47 <= 12
x57 <= 18
x61 <= 62
x71 <= 305
x31 <= 21
x41 <= 72
x51 <= 88
END
LEAVE
LP OPTIMUM FOUND AT STEP  9

OBJECTIVE FUNCTION VALUE

1)  679363.000

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MODEL 7. MAXIMUM DEMAND WITH SHIP CAPACITY 500 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
 + 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 500 ! link 1-2;
x25 + x14 <= 500 ! link 2-3;
x25 + x14 + x37 + x31 <= 500 ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 500 ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 500
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 500
x61 + x51 + x71 + x31 + x41 <= 500
x25 <= 33 ! Average demand in market 2-5;
x14 <= 58 ! etc.;
x37 <= 16
x47 <= 12
x57 <= 18
x61 <= 62
x71 <= 305
x31 <= 21
x41 <= 72
x51 <= 88
END
LEAVE
LP OPTIMUM FOUND AT STEP 10

OBJECTIVE FUNCTION VALUE

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RIGHTHAND SIDE RANGES

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MODEL 8. MAXIMUM DEMAND WITH SHIP CAPACITY 750 TEUS

MAX 291 x25 + 1650 x14 + 434 x37 + 620 x47 + 540 x57
+ 1980 x61 + 1383 x71 + 1230 x31 + 815 x41 + 1397 x51

ST
x14 <= 750 ! link 1-2;
x25 + x14 <= 750 ! link 2-3;
x25 + x14 + x37 + x31 <= 750 ! link 3-4;
x25 + x37 + x47 + x31 + x41 <= 750 ! etc.;
x37 + x47 + x57 + x51 + x31 + x41 <= 750
x37 + x47 + x57 + x61 + x51 + x31 + x41 <= 750
x61 + x51 + x71 + x31 + x41 <= 750
x25 <= 33 ! Average demand in market 2-5;
x14 <= 58 ! etc.;
x37 <= 16
x47 <= 12
x57 <= 18
x61 <= 62
x71 <= 305
x31 <= 21
x41 <= 72
x51 <= 88
END
LEAVE
LP OPTIMUM FOUND AT STEP   10

OBJECTIVE FUNCTION VALUE

1)  881428.000

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NO. ITERATIONS=   10
RANGES IN WHICH THE BASIS IS UNCHANGED:

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APPENDIX B: FLEET IMPACT INPUT AND OUTPUT FILES

This appendix has two pairs of input and output files. The input files are NAmMax.IN and NAmAver.IN, which are partly based on the data in Tables 4-1, and 4-2. They use the average and maximum freight demand for the North American route of the ocean liner discussed in Ch. 4. Two output files then follow. They are NAmMax.OUT and NAmAver.OUT.
NAmMax.IN input file:

INPUT
NAmerica_Max
TEU
290

7
1  2  117  24  13  1752
2  3  40   13  13   603
3  4  28   13   5   418
4  5  19   5   5   292
5  6  52   5   2   772
6  7  13   2  14   189
7  1 117  14  24  1752

10
58  1650  1  2  3  4
33  291   2  3  4  5
21 1230  3  4  5  6  7  1
16  434  3  4  5  6  7
72  815  4  5  6  7  1
12  620  4  5  6  7
18  540  5  6  7
88 1397  5  6  7  1
62 1980  6  7  1
305 1383 7  1

7
ISREK
CANAR
USBOS
USNYC
USNRF
CAHAL
CANAR
2
27
35
15
0
11
0
0
0
0
10
NAmAver.IN input file:

INPUT
NAmerica_Aver
TEU
290
7
  1 2 117 24 13 1752
  2 3 40 13 13 603
  3 4 28 13 5 418
  4 5 19 5 5 292
  5 6 52 5 2 772
  6 7 13 2 14 189
  7 1 117 14 24 1752
10
  46 1650 1 2 3 4
  26 291 2 3 4 5
  15 1230 3 4 5 6 7 1
  11 434 3 4 5 6 7
  55 815 4 5 6 7 1
  9 620 4 5 6 7
  14 540 5 6 7
  69 1397 5 6 7 1
  45 1980 6 7 1
  244 1383 7 1
7
ISREK
CANAR
USBOS
USNYC
USNRF
CAHAL
CANAR
5
35
44
0
0
0
0
0
0
0
0
**NamMax.OUT output file:**

**************************************************************************
*  
* FLEET IMPACT  
*  
* Optimization Software for Fleet Planning  
*  
* Copyright (C) 1994 Viglundur T. Viglundsson  
*  
**************************************************************************

Time: 10:05:54
Date: 05.05.1994
Route name: "NAmerica_Max"
Input file is: NAMMAX.IN
This file is: NAMMAX.OUT

**************************************************************************
** INPUT DATA ****************************
**************************************************************************

Ship capacity: 290 TEUs
Length of route cycle: 5778
Route cycle time (hrs/days): 462/19.3
Nr. of route links: 7
Nr. of O-D markets: 10
Nr. of port calls : 7

ROUTE DATA:

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<th>Port pair</th>
<th>Voyage time</th>
<th>First port time</th>
<th>Second port time</th>
<th>Distance</th>
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<tbody>
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<td>603</td>
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<td>14</td>
<td>189</td>
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<tr>
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<td>CANAR-ISREK</td>
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<td>14</td>
<td>24</td>
<td>1752</td>
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**FREIGHT DATA:**

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<th>Origin/Dest.</th>
<th>Avail. Freight (TEUs)</th>
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<td>2 - 5</td>
<td>CANAR/USNRF</td>
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<tr>
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<td>USBOS/ISREK</td>
<td>21</td>
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<td>3 - 7</td>
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<tr>
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</table>
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**OUTPUT DATA ****************************

**LINEAR PROGRAM (LP) OUTPUTS:**

Total spill at LP optimum is: 258 TEUs
Total net freight revenues at LP optimum are: 568723

**LP RESULTS. FREIGHT TO CARRY IN EACH O-D (TEUs):**

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<th>Spill</th>
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<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
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<td>21</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>ALL</td>
<td>0</td>
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<td>72</td>
</tr>
<tr>
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<td>USNYC/CANAR</td>
<td>ALL</td>
<td>0</td>
</tr>
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<td>USNRF/CANAR</td>
<td>ALL</td>
<td>0</td>
</tr>
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<td>CAHAL/ISREK</td>
<td>ALL</td>
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</tr>
<tr>
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<td>165</td>
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```
SYSTEM-WIDE OUTPUTS:

Available Container-Miles (ACMs): 1675620
Revenue Container-Days (RCDs): 2879
Revenue Container-Miles (RCMs): 867599
Average Load Factor (ALF): 51.8%

ROUTE LINK OUTPUTS:

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<th>RCDs</th>
<th>LF (%)</th>
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REVENUE CONTAINER-DAYS (RCDs) BY O-D MARKET:

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<tr>
<td>5 - 7</td>
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PERISHABLES DEPRECIATION ANALYSIS:

Deprec. per day: 2.0%
System-wide loss: 13.7%
Total Perishable Cargo: 41 TEUs

PERISHABLES VALUE DEPR. BY O-D MARKET:

<table>
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<tr>
<th>O-D mkt</th>
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<th>Perish. Carried</th>
<th>Depr. (% of value)</th>
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<td>CANAR/USNRF</td>
<td>11.6</td>
<td>9.5</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNRF/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNRF/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>14.0</td>
<td>11.3</td>
</tr>
</tbody>
</table>

******************** END OF FLEET IMPACT ********************
NAMAVER.OUT output file:

********************************************************************
* FLEET IMPACT *
* Optimization Software for Fleet Planning *
* Copyright (C) 1994 Viglundur T. Viglundsson *
********************************************************************

Time: 10:06:09
Date: 05.05.1994
Route name: "NAmerica_Aver"
Input file is: NAMAVER.IN
This file is: NAMAVER.OUT

************************* INPUT DATA ****************************
Ship capacity: 290 TEUs
Length of route cycle: 5778
Route cycle time (hrs/days): 462/19.3
Nr. of route links: 7
Nr. of O-D markets: 10
Nr. of port calls: 7

ROUTE DATA:

<table>
<thead>
<tr>
<th>Link#</th>
<th>Port pair</th>
<th>Voyage time</th>
<th>First port time</th>
<th>Second port time</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ISREK-CANAR</td>
<td>117</td>
<td>24</td>
<td>13</td>
<td>1752</td>
</tr>
<tr>
<td>2</td>
<td>CANAR-USBOS</td>
<td>40</td>
<td>13</td>
<td>13</td>
<td>603</td>
</tr>
<tr>
<td>3</td>
<td>USBOS-USNYC</td>
<td>28</td>
<td>13</td>
<td>5</td>
<td>418</td>
</tr>
<tr>
<td>4</td>
<td>USNYC-USNRF</td>
<td>19</td>
<td>5</td>
<td>5</td>
<td>292</td>
</tr>
<tr>
<td>5</td>
<td>USNRF-CAHAL</td>
<td>52</td>
<td>5</td>
<td>2</td>
<td>772</td>
</tr>
<tr>
<td>6</td>
<td>CAHAL-CANAR</td>
<td>13</td>
<td>2</td>
<td>14</td>
<td>189</td>
</tr>
<tr>
<td>7</td>
<td>CANAR-ISREK</td>
<td>117</td>
<td>14</td>
<td>24</td>
<td>1752</td>
</tr>
</tbody>
</table>
FREIGHT DATA:

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Avail. Freight (TEUs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>46</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>26</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>15</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>11</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>55</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNYC/CANAR</td>
<td>9</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>14</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>69</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>45</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>244</td>
</tr>
</tbody>
</table>

OUTPUT DATA

LINEAR PROGRAM (LP) OUTPUTS:

Total spill at LP optimum is: 138 TEUs
Total net freight revenues at LP optimum are: 523442

LP RESULTS. FREIGHT TO CARRY IN EACH O-D (TEUs):

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Avail.Frt.</th>
<th>To carry</th>
<th>Spill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>46</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>26</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>15</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>11</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>55</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNYC/CANAR</td>
<td>9</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>14</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>69</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>45</td>
<td>ALL</td>
<td>0</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>244</td>
<td>153</td>
<td>91</td>
</tr>
</tbody>
</table>
SYSTEM-WIDE OUTPUTS:

Available Container-Miles (ACMs): 1675620
Revenue Container-Days (RCDs): 2723
Revenue Container-Miles (RCMs): 822791
Average Load Factor (ALF): 49.1%

ROUTE LINK OUTPUTS:

<table>
<thead>
<tr>
<th>Link#</th>
<th>Port pair</th>
<th>RCMs</th>
<th>RCDs</th>
<th>LF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ISREK-CANAR</td>
<td>80592</td>
<td>260</td>
<td>15.9</td>
</tr>
<tr>
<td>2</td>
<td>CANAR-USBOS</td>
<td>43416</td>
<td>159</td>
<td>24.8</td>
</tr>
<tr>
<td>3</td>
<td>USBOS-USNYC</td>
<td>40964</td>
<td>151</td>
<td>33.8</td>
</tr>
<tr>
<td>4</td>
<td>USNYC-USNRF</td>
<td>20148</td>
<td>69</td>
<td>23.8</td>
</tr>
<tr>
<td>5</td>
<td>USNRF-CAHAL</td>
<td>97272</td>
<td>291</td>
<td>43.4</td>
</tr>
<tr>
<td>6</td>
<td>CAHAL-CANAR</td>
<td>32319</td>
<td>150</td>
<td>59.0</td>
</tr>
<tr>
<td>7</td>
<td>CANAR-ISREK</td>
<td>508080</td>
<td>1643</td>
<td>100.0</td>
</tr>
</tbody>
</table>

REVENUE CONTAINER-DAYS (RCDs) BY O-D MARKET:

<table>
<thead>
<tr>
<th>O-D market</th>
<th>Origin/Dest.</th>
<th>RCDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>432</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>124</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>171</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>63</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNYC/ISREK</td>
<td>79</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNYC/CANAR</td>
<td>38</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>45</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>611</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>294</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>867</td>
</tr>
</tbody>
</table>
PERISHABLES DEPRECIATION ANALYSIS:

Deprec. per day:  5.0%
System-wide loss:  37.3%
Total Perishable Cargo:  28 TEUs

PERISHABLES VALUE DEPR. BY O-D MARKET:

<table>
<thead>
<tr>
<th>O-D mkt</th>
<th>Origin/Dest.</th>
<th>Perish. Carried</th>
<th>Depr. (% of value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>ISREK/USNYC</td>
<td>16.1</td>
<td>47.0</td>
</tr>
<tr>
<td>2 - 5</td>
<td>CANAR/USNRF</td>
<td>11.4</td>
<td>23.8</td>
</tr>
<tr>
<td>3 - 1</td>
<td>USBOS/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 - 7</td>
<td>USBOS/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 1</td>
<td>USNRC/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 - 7</td>
<td>USNRC/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 7</td>
<td>USNRF/CANAR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 - 1</td>
<td>USNRF/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 - 1</td>
<td>CAHAL/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7 - 1</td>
<td>CANAR/ISREK</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

************************ END OF FLEET IMPACT ************************
APPENDIX C: FLEET IMPACT PASCAL SOURCE CODE

This appendix includes the software source code for the fleet planning program FLEET IMPACT introduced in Ch. 3. The code is written in the Pascal programming language, using a Personal Computer (PC). The compiler used was Turbo Pascal, version 5.5 for MS-DOS, from Borland. In conjunction with this thesis there is a 3.5" floppy disk containing the source code, Impact.PAS, executable file, Impact.EXE, help file Help.DAT, and Video.CFG, along with two example input files. Impact.EXE can be run on any PC-computer with a MS-DOS operating system.
Program FleetImpact;

Uses Dos, Crt, Graph, GrDriver, GrFont, Printer, PDsLib;

Const MaxLnks = 30; { MAXIMUM NUMBER OF LINKS }
    MaxOD = 30; { MAXIMUM NUMBER OF O-D MARKETS }
    MaxPrtCl = 30; { MAXIMUM NUMBER OF PORT CALLS }

    { PART OF SIMPLEX ROUTINE }
    n = MaxOD; { MAX NO. OF DECISION VARIABLES }
    m = MaxLnks + MaxOD; { MAX NO. OF CONSTRAINTS }
    np = n + 1;
    mp = m + 1;

Label 100; { USED IN MAIN PROGRAM }

Type String5 = String[5];
    String20 = String[20];
    RtDataX = array[1..6,1..MaxLnks] of extended;
    ODdataX = array[1..MaxPrtCl,1..MaxOD] of extended;
    PrtNameX = array[1..MaxPrtCl] of String5;
    LinkcrX = array[1..MaxLnks] of extended;

    { PART OF SIMPLEX ROUTINE }
    RealArrayMPbyNP = array [1..mp,1..np] of real;
    IntegerArrayN = array [1..n] of integer;
    IntegerArrayM = array [1..m] of integer;
    IntegerArrayNP = array [1..np] of integer;

Var Inn_Skra, Ut_Skra, VerkNafn, CargUnit: String20;
    RtData: RtDataX;
    ODdata: ODdataX;

    a: RealArrayMPbyNP; { PART OF SIMPLEX ROUTINE, SEE BELOW }

    PortName: PrtNameX;
    Linkcrgo, PrcFresh: LinkcrX;
    RCM, RCD, RCD_OD, LF_link, ODdepn : LinkcrX;
    ShipSize, RtLength, FishDepn: extended;
    ACM, RCM_SW, RCD_SW, LF_SW : extended;
    i, j, Nlinks, NrODmkt, NrPortCl: integer;
    Run, pass, Flag: boolean;
    Answer: char;
    MenuFlag, MenFlag2: boolean;
    RPFlag, ODFlag, PCFlag, PGFlag: boolean;

{ ------------------------------- }

{ THE ABOVE VARIABLES ARE AS FOLLOWS: }

    Inn_Skra is name of input file to save in (sub-menu) or run (main).
    Ut_Skra is output file to write Fleet Impact output to.
VerkNafln is project or route name (at top of file/input).
CargUnit is unit of freight (either TEU or Ton).

RtDataX[6, MaxLnks] holds the route properties data:
- RtData[1,i] is former node point (i) that link i connects to.
- RtData[2,i] is latter node point (i+1) that link i connects to.
- RtData[3,i] is voyage time on link i
- RtData[4,i] is port time at node i
- RtData[5,i] is port time at node i+1
- RtData[6,i] is distance of link i

ODdata[NrPortCl, NrODmkts] holds the Origin-Destination data:
- ODdata[1,i] is amount of freight in O-D market i.
- ODdata[2,i] is Net revenue per unit freight in O-D market i.
- ODdata[3,i] is Origin node/port of that freight.
- ODdata[k,i] is node/port in path of that freight (k=4,...,N-1).
- ODdata[N,i] is Destination node/port of freight.

a[mp, np] is the array holding simplex table inputs and outputs.
a[i,j] is formatted such that i is line in table, and j is column.

BEFORE procedure Simplx is run:
- a[1,1] is zero.
- a[1,j] is net freight rev. in O-D mkt (j-1), (j=2,...,NrODmkts+1).
- a[i,1] is ShipSize (Capacity) of link (i-1), (i=2,...,Nlinks+1).
- a[i,j] is -coeffic. of decision var. of O-D market (i-1), in link constraint (j-1), (i=2,...,Nlinks+1, j=2,...,NrODmkts+1).
- a[i,j] is -coeffic. of dec. var. of O-D market (i-1), in freight constraint (j-1), (i=Nlinks+2,...,Nlinks+NrODmkts+1, j=2,...,NrODmkts+1).

AFTER procedure Simplx is run:
- a[1,1] is maximum of objective function (max. freight revenues).
- a[(iposv[k]),1] is value of dec. variable X with subscript iposv[k]. The vector iposv[] contains dec. and slack variables that are in basis. Variable X is a slack variable if iposv[] is > NrODmkts. Variables not in iposv[] can be set to 0.

PortName[i] is name of port at port call i (i=1..NrPortCl).
Linkcrgo[i] is amount of cargo on each link (i=1..Nlinks).
PrcFresh[i] is % of total cargo in O-D mkt i that is perishable (i=1..NrODmkts)
RCM[i] is Rev. Container-miles (or Ton-miles) on link i.
RCD[i] is Rev. Container-days (or Ton-days) on link i.
RCD_OD[i] is Rev. Container-days (or Ton-days) for O-D mkt i.
LF_Link[i] is Load factor on link i (i=1..Nlinks).
ODdepn[i] is depr. in O-D market i.

ShipSize is capacity of ship (Tons or TEUs).
FishDepn is depreciation per day of the perishable.
ACM is system-wide (SW) Available Container (or Ton) miles.
RCM_SW is SW Rev. Container-miles (or Ton-miles).
RCM_SD is SW Rev. Container-days (or Ton-days).
LF_SW is SW Load factor.
Nlinks is number of links of each run.
NrODmkts is number of O-D markets in run.
NrPrtCl is number of port calls per route cycle.

Run is a dummy used in Main Menu Repeat in main program.
Pass is used in Main Menu command 2. If input file was read
   successfully Pass becomes True and Fleet Impact processor runs, (see main program) else do not run
   processor (Pass = False)
Flag is true if program is quitting and procedure should show
   end picture ('End of Fleet Impact'), else False.
Answer is submenu command selection ('0', '1', etc).
MenuFlag is True if horiz. lines in main menu should be drawn along
   with rest of main menu but False if not (e.g. if coming from
   submenu).
MenFlag2 serves the same purpose for the sub-menu.
RPFlag, ODFlag, PCFlag, PGFlag are True if inputs have been entered
   for each command in submenu. If True then paint that command
   gray, else white. 

{ ----------------------------------------------------------- }

procedure Center( y : integer;
                   message : String);

   { CENTER MESSAGE AT ROW Y, CLEARING LINE }
begin
   GoToXY(1, y);
   ClrEOL;
   write(message:40 + (Length(message) DIV 2))
end;

{ ----------------------------------------------------------- }

procedure Erase_White5(var Strng: String5);

   { ERASES ANY EMPTY SPACES (' ') IN INPUT STRING }
var C, C: integer;

begin
   C:= 1;
   for Cl:=1 to Length(Strng) do
      if Strng[Cl] <> '' then
         begin
            Strng[C]:= Strng[Cl];
            C:= succ(C);
         end;
end;
procedure Erase_White20(var Strng: String20);
    { ERASES ANY EMPTY SPACES (' ') IN INPUT STRING }
var C, Cl: integer;
begin
    C:= 1;
    for Cl:=1 to Length(Strng) do
        if Strng[Cl] <> ' ' then
            begin
            Strng[C]:= Strng[Cl];
            C:= succ(C);
            end;
    Strng[0]:= chr(C - 1);
end;

procedure BumpStrUp5( var s: String5);
    { CONVERT STRING s TO ALL-UPPERCASE }
var i: integer;
begin
    for i:=1 to Length(s) do
        s[i]:= Upcase(s[i]);
end;

procedure BumpStrUp20( var s: String20);
    { CONVERT STRING s TO ALL-UPPERCASE }
var i: integer;
begin
    for i:=1 to Length(s) do
        s[i]:= Upcase(s[i]);
end;
procedure Flush_KB_Buffer;

   { FLUSHES KEYBOARD OF "BAD" PREVIOUS KEYSTROKES }

var Ch : char;

begin
   while KeyPressed do
      Ch:= ReadKey;
   end;

{ ----------------------------------------------- }

procedure Cursor_Off;

   { TURNS OFF THE CURSOR TO HAVE 'CLEAN' MENUS } }

var Regs : Registers;

begin
   Regs.AX:= $0100;
   Regs.CX:= $2000;
   Intr($10,Regs);
end;

{ ----------------------------------------------- }

procedure Cursor_On;

   { TURNS CURSOR ON AGAIN }

var Regs : Registers;

begin
   Regs.AX:= $0F00;
   Intr($10,Regs);

   if ((Regs.AX) and ($0007)) = $0007 then { MONO MODE }
      Regs.CX:= $0C0D
   else { COLOR MODE }
      Regs.CX:= $0607;
      Regs.AX:= $0100;
      Intr($10,Regs);
   end;

{ ----------------------------------------------- }
procedure Pictures(Flag:boolean);

{ SHOWS BEGINNING OR END PICTURES, DEPENDING ON Flag }

var Gd, Gm, x, y: integer;

begin
  DetectGraph(Gd, Gm);  { FINDS "BEST" GRAPH DRIVER, Gd }
  InitGraph(Gd, Gm,'');
  if GraphResult <> grOk then
    Halt(1);

  { IF Flag = True THEN SHOW END PICTURE (AFTER 'QUIT') }
  { IF Flag = False THEN SHOW BEGINNING PICTURES }

  { IF PROGRAM IS STARTING: SHOW THIS PART ON SCREEN }
  if (Flag = False) then
    begin
      SetBkColor(Blue);  { BLUE BACKGROUND }
      SetColor(White);  { WHITE LETTERS }
      Rectangle(0,0,GetMaxX,GetMaxY);  { WHITE BORDER }

      { FIRST PICTURE AT PROGRAM STARTUP }
      SetTextStyle(TriplexFont,0,7);
      SetTextJustify(1,1);  { TEXT JUSTIFIED }
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 - 10,'Fleet Impact');
      delay(2200);

      { WIPE OUT FIRST PICTURE WORDS BY WRITING OVER }
      SetColor(Blue);
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 - 10,'Fleet Impact');
      delay(800);

      { SECOND PICTURE AT PROGRAM STARTUP }
      SetColor(White);  { NEW TEXT }
      SetTextStyle(TriplexFont,0,4);
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 - 67,
               'Route Optimization Software');
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1,'for');
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 + 67,
               'Ocean Liner Fleets');
      delay(2600);

      { WIPE OUT SECOND PICTURE WORDS }
      SetColor(Blue);
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 - 67,
               'Route Optimization Software');
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1,'for');
      OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 + 67,
               'Ocean Liner Fleets');
      delay(500);
RestoreCrtMode;  { QUIT TEMPORARILY IN GRAPHICS MODE }
TextColor(White);  { WHITE LETTERS FOR MAIN MENU }
TextBackground(Blue);  { BLUE BACKGROUND FOR MAIN MENU }
ClrScr;
end;  { IF Flag = False }

{ IF PROGRAM IS ENDING ('QUIT') SHOW THIS PICTURE ON SCREEN }
if (Flag = True) then
begin
  SetGraphMode(Gm);
  SetBkColor(Blue);
  SetColor(White);
  Rectangle(0,0,GetMaxX,GetMaxY);
  SetTextStyle(TriplexFont,0,5);
  SetTextJustify(1,1);
  OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 -40,'End of');
  OutTextXY(GetMaxX Div 2 +1,GetMaxY Div 2 +1 +40,'Fleet Impact');
  delay(1800);
  CloseGraph;  { SHUT DOWN GRAPHICS PERMANENTLY }
end;  { IF Flag = True }
end;  { PROCEDURE Pictures }

{ -------------------------------------------------- }

procedure Draw_Menu_Lines;

{ DRAWS HORIZONTAL LINES IN MENUS. }
{ SCREEN IS 24 LINES IN VGA MODE }
{ PROCEDURE ONLY RUN IF MenuFlag/ MenFlag2 ARE FALSE }

var i:integer;

begin
  ClrScr;
  GoToXY(9,3);
  writeln('_______________________________________',
          '_______________________________________');
  GoToXY(9,23);
  writeln('_______________________________________',
          '_______________________________________');
  end;

{ -------------------------------------------------- }
procedure Clean_Menu;

{ CLEANS MENUS EXCEPT FOR HORIZ LINES AT BOTTOM AND TOP
 => NO FLICKER WHEN EXITING MENU. ONLY RUN IF
 MenuFlag/ MenFlag2 ARE TRUE }

var y: integer;

begin
  for y:=5 to 21 do
    begin
      GoToXY(1,y);
      ClrEoL;
    end;
end;

{ --------------------------------

procedure Draw_Main_Menu;

{ DRAWS PICTURE OF MAIN MENU ON SCREEN }

begin
  Cursor_Off;

  if MenuFlag = False then
    begin
     ClrScr;  { IF HAVE TO TOTALLLY REDRAW MENU }
      Draw_Menu_Lines;
    end
  else
    Clean_Menu;  { ELSE ONLY REDRAW TEXT IN MENU }

  MenuFlag:= False;

  GoToXY(30,5);
  writeln('');
  GoToXY(30,6);
  writeln(' MAIN MENU');
  GoToXY(30,7);
  writeln('');

  GoToXY(30,9);
  writeln('0 Quit Fleet Impact');

  GoToXY(30,11);
  writeln('1 Input Sub-Menu');

  GoToXY(30,13);
  writeln('2 Run Fleet Impact');

GoToXY(30,15);
writeln('3 View Output');

GoToXY(30,17);
writeln('4 Print Output');

GoToXY(30,19);
writeln('5 View Any File');

GoToXY(30,21);
writeln('6 Help');

end; { PROCEDURE Draw_Main_Menu }

{ ------------------------------- }

procedure Draw_Input_Submenu;

{ DRAWS PICTURE OF INPUT SUBMENU ON SCREEN }

begin
  Cursor_Off;
  if MenFlag2 = False then
    begin
      ClrScr;  { IF HAVE TO TOTALLY REDRAW MENU }
      Draw_Menu_Lines;
    end
  else
    Clean_Menu;  { ELSE ONLY REDRAW TEXT IN MENU (NO FLICKER) }

  MenFlag2:= False;

  GoToXY(30,5);
  writeln('                                 ');  
  GoToXY(30,6);
  writeln('INPUT SUBMENU');
  GoToXY(30,7);
  writeln('                                ');

  GoToXY(30,9);
  writeln('0 Exit to Main Menu');

  GoToXY(30,11);
  writeln('1 Route Properties');

  GoToXY(30,13);
  writeln('2 Origin-Destination Data');

  GoToXY(30,15);
  writeln('3 Port Call Names');
GoToXY(30,17);
writeln('4 Perishable Goods Data');

GoToXY(30,19);
writeln('5 Save Inputs to File');

{ THE REMAINING CODE PAINTS LETTERS GRAY TO VERIFY INPUT }

{ ROUTE PROPERTIES COMMAND IN GRAY }
if (RPFlag = True) then
begin
   TextColor(LightGray);
   GoToXY(30,11);
   writeln('1 Route Properties');
   TextColor(White);
end;

{ ORIGIN-DESTINATION INPUT COMMAND IN GRAY }
if (ODFlag = True) then
begin
   TextColor(LightGray);
   GoToXY(30,13);
   writeln('2 Origin-Destination Data');
   TextColor(White);
end;

{ PORT CALL NAMES COMMAND IN GRAY }
if (PCFlag = True) then
begin
   TextColor(LightGray);
   GoToXY(30,15);
   writeln('3 Port Call Names');
   TextColor(White);
end;

{ PERISHABLE GOODS DATA COMMAND IN GRAY }
if (PGFlag = True) then
begin
   TextColor(LightGray);
   GoToXY(30,17);
   writeln('4 Perishable Goods Data');
   TextColor(White);
end;
end; { PROCEDURE Draw_Input_Submenu }

{ ------------------------------------------------- }
procedure Are_You_Sure;

{ DO YOU REALLY WANT TO QUIT? }

var s: char;
    Flag: boolean;

begin
    GoToXY(23,24);
    TextColor(White+Blink); { MAKE FOLLOWING TEXT BLINK }
    writeln(' Really want to quit? (Y/N) ');
    Sound(1000);
    delay(200);
    NoSound;

    TextColor(Yellow+Blink); { MAKE FOLLOWING TEXT BLINK }
    GoToXY(49,24);
    write('Y');
    GoToXY(51,24);
    write('N');
    TextColor(White);

    GoToXY(54,24);
    Repeat
        s := UpCase(ReadKey);
    Until s in ['Y','N'];

    if (s = 'Y') then { IF WANT TO QUIT THEN }
    begin
        Flag:= True;
        Pictures(Flag);
        TextBackGround(Black);
        ClrScr; { LEAVES BACKGROUND BLACK IN DOS }
        TextBackGround(Blue);
        writeln('End of Fleet Impact');
        writeln('Copyright (C) 1994 Viglundur T. Viglundsson');
        { BACKGROUND BLACK IN DOS, LETTERS WHITE ON BLUE }

        TextBackGround(Black);
        Cursor_On; { RESTORE CURSOR }
        Halt; { COMPLETELY HALTS THE PROGRAM (QUIT) } 
    end;

end; { PROCEDURE Are_You_Sure }
procedure Print_Output(var Ut_Skra: String20);

    { PRINTS OUTPUT TO PRINTER }

var InFile: text;
    Ch, sv: char;
    s : String[132];

begin
    if (Ut_Skra = 'qweasad') then { IF NO INPUT HAS BEEN PROCESSED }
        begin
            Clean_Menu;
            Cursor_On;
            Center(13,'No input has been processed yet, press any key...');
                { CENTERS ABOVE MESSAGE ON SCREEN AT LINE 13 }

            Flush_KB_Buffer;
            Ch:= ReadKey;
            Cursor_Off;
            MenuFlag:= True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }
            Exit; { FILE DOES NOT EXIST => EXIT TO MAIN MENU }
        end; { if Ut_Skra }

    if Printer_Ready(0) then { IF PRINTER ON AND READY }
        begin
            Assign(Infile, Ut_Skra);
            Reset(Infile);
            Clean_Menu;
            Cursor_On;
            Center(13,'Is a printer connected to port LPT1? (Y/N): ');
                { ASK TO BE SURE SO AS TO AVOID ACCIDENTAL PRINTING }
           TextColor(Yellow); { HAVE 'Y' AND 'N' IN YELLOW }
            GoToXY(57,13);
            write('Y');
            GoToXY(59,13);
            write('N');
            GoToXY(63,13);
            TextColor(White);
            Repeat
                sv := UpCase(ReadKey);
                Until sv in ['Y','N'];

                { DON'T WANT TO PRINT => EXIT TO MAIN MENU }
            if (sv = 'N') then
                begin
                    Center(13,'Printing canceled, press any key...');
                    Flush_KB_Buffer;
                    Ch:= ReadKey;
                    Cursor_Off;
                    MenuFlag:= True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }
                    Exit;
                end;
        end;
MenuFlag:= True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }

while not Eof( InFile ) do begin
    readln( InFile, s );
    writeln( Lst , ', ', s );
end; { while not EOF }

Flush_KB_Buffer;
Ch:= ReadKey; { WAIT WHILE ABOVE MESSAGE DISPLAYED }
Cursor_Off;

Close(InFile);
end
else begin
    Clean_Menu;
    Cursor_On;
    Center(13,'Printer not ready, press any key...'); { CENTERS ABOVE MESSAGE ON SCREEN AT LINE 13 }
    Flush_KB_Buffer;
    Ch:= ReadKey;
    Cursor_Off;
    MenuFlag:= True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }
    Exit; { FILE DOES NOT EXIST => EXIT TO MAIN MENU }
end; { if Printer_Ready(0) }
end; { PROCEDURE Print_Output }

procedure Route_Data( var CargUnit,
    Verknafn : String20;
    var ShipSize : extended;
    var Nlinks : integer;
    var RtData : RtDataX);

    { READS IN ROUTE DATA FROM KEYBOARD (COMMAND 1 IN SUBMENU) }

var i, j, e: integer;
    s: char;
    Sd: String[20];

begin
    ClrScr;
    Cursor_On;
RPFlag := True; { DATA HAS BEEN/IS BEING READ IN (GRAY LETTERS) } writeln;
MenFlag2 := False; { MUST REDRAW WHOLE SUBMENU NEXT TIME }

write(' Route name: ');
readln(VerkNafn);
writeln;

write(' Is freight in TEUs (press C), or Tons (press T): ');
TextColor(Yellow);
GoToXY(28, 4);
write('C');
GoToXY(47, 4);
write('T');
TextColor(White);
GoToXY(51, 4); { KEEPS CURSOR BEHIND PROMPT }
Repeat
  s := UpCase(ReadKey);
Until s in ['C', 'T'];

if (s = 'C') then
  begin
    writeln('TEUs');
    CargUnit := 'TEU'
  end
else
  begin
    writeln('Tons');
    CargUnit := 'Ton'
  end;
writeIn;
Repeat
  Repeat
    write(' Capacity of ship (' , CargUnit , ',') : ');
    readln(Sd);
    Val(Sd, ShipSize, e);
    { Val() ENSURES THAT CORRECT VARIABLE TYPE 
      WAS ENTERED (=> NO CRASH) }
  Until (e = 0); { CANNOT COMBINE THESE TWO 'UNTILS' }
  Until (ShipSize > 0);
  { e IS 0 IF CORRECT VARIABLE TYPE WAS ENTERED }
writeln;
Repeat
  Repeat
    write(' Number of route links (< ', l + MaxLnks , ','): ');
    readln(Sd);
    Val(Sd, NLinks, e);
  Until (e = 0)
Until ((Nlinks <= MaxLnks) and (Nlinks > 0)); { CORRECT RANGE }
writeln; { CANNOT COMBINE THESE TWO 'UNTILS' }
for i:=1 to 6 do
  begin
    for j:=1 to MaxLnks do
      RtData[i,j]:=0.0;
  end;

for i:= 1 to Nlinks do
  begin
    RtData[1,i]:= i;
    if (i = Nlinks) then { IF LAST LINK THEN SECOND NODE IS 1 }
      RtData[2,i]:= 1
    else
      RtData[2,i]:= i+1;

  Repeat
    Repeat
      if (i = Nlinks) then { IF LAST LINK THEN SECOND NODE IS 1 }
        write(' Voyage time on link ',i,
             ' (node ',i,' to node 1) in hours: ')
      else
        write(' Voyage time on link ',i,' (node ',i,
             ' to node ',i+1,) in hours: ');
      readln(Sd);
      Val(Sd, RtData[3,i], e);
  Until (e = 0);
  Until (RtData[3,i] > 0); { CANNOT COMBINE THESE TWO 'UNTILS' }

  Repeat
    Repeat
      write(' Port time in Originating port of link ',
           i,' (hrs): ');
      readln(Sd);
      Val(Sd, RtData[4,i], e);
  Until (e = 0);
  Until (RtData[4,i] > 0); { CANNOT COMBINE THESE TWO 'UNTILS' }

  Repeat
    Repeat
      write(' Port time in Destination port of link ',
           i,' (hrs): ');
      readln(Sd);
      Val(Sd, RtData[5,i], e);
  Until (e = 0);
  Until (RtData[5,i] > 0); { CANNOT COMBINE THESE TWO 'UNTILS' }

  Repeat
    Repeat
      write(' Length of link ',i,' (miles): ');
      readln(Sd);
      Val(Sd, RtData[6,i], e);
  Until (e = 0);
  Until (RtData[6,i] > 0); { CANNOT COMBINE THESE TWO 'UNTILS' }
writeln;
end; { for i := 1 to Nlinks }
end; { PROCEDURE Route_Data }

{ ----------------------------------------------- }

procedure Origin_Destination_Data( var CargUnit : String20;
  var NrODmkts : integer;
  var ODdata : ODdataX);

{ READS IN O-D DATA FROM KEYBOARD (COMMAND 2 IN SUBMENU) }

var i, j, e, tempo: integer;
s: char;
Sd: String[20];

begin
  ClrScr;
  Cursor_On;
  ODFlag:= True;

  writeln;
  write( 'Is freight data in TEUs (press C), or Tons (press T): ');

  TextColor(Yellow);
  GoToXY(33,2);
  write( 'C' );
  GoToXY(52,2);
  write( 'T' );
  TextColor(White);
  GoToXY(56,2);

  Repeat
    s := UpCase(ReadKey);
  Until s in [ 'C', 'T' ];

  if (s = 'C') then
    begin
      writeln('TEUs');
      CargUnit:= 'TEU'
    end
  else
    begin
      writeln('Tons');
      CargUnit:= 'Ton'
    end;

  writeln;
Repeat
  Repeat
    write(' Number of Origin-Destination (O-D) markets (< ', MaxOD+1, '): ');
    readln(Sd);
    Val(Sd, NrODmkts, e);
    Until (e = 0);
    Until ((NrODmkts <= MaxOD) and (NrODmkts > 0));
  
  for i:=1 to MaxPrtCl do
    begin
      for j:=1 to MaxOD do
        ODdata[i,j]:=0.0;
    end;

  for i:=1 to NrODmkts do
  begin
    writeln;
    Repeat
      Repeat
        write(' Amount of freight in O-D market ',i,' (', CargUnit, 's): ');
        readln(Sd);
        Val(Sd, ODdata[1,i], e);
        Until (e = 0);
        Until (ODdata[1,i] > 0);
      end;

    Repeat
      Repeat
        write(' Net freight revenue per ', CargUnit, ' in O-D market ',i,': ');
        readln(Sd);
        Val(Sd, ODdata[2,i], e);
        Until (e = 0);
        Until (ODdata[2,i] > 0);
      end;

    Repeat
      Repeat
        write(' Originating node of freight in O-D market ',i,': ');
        readln(Sd);
        Val(Sd, ODdata[3,i], e);
        Until (e = 0);
        Until ((ODdata[3,i] > 0) and (ODdata[3,i] <= MaxOD));
j:=3;
while ODdata[j,i] <> 0 do
    begin
        j:=j+1;
        Repeat
            write(' Next node in path of freight in O-D ',i,
                 ' <Enter 0 to end input>: ');
            readln(Sd);
            Val(Sd, ODdata[j,i], e);
            Until (e = 0);
        end; { WHILE }
    end; { for i:=1 to NrODmkts }
end; { PROCEDURE Origin_Destination_Data }

{ ----------------------------------------------- }

procedure Port_Names( var NrPortCl,
        Nlinks : integer;
        var PortName : PrtNameX);

    { READS IN PORT CALL NAMES FROM KEYBOARD (COMMAND 3 IN SUBMENU) }

var i, j, e: integer;
    Sd, Tempo: String5;

begin
    ClrScr;
    Cursor_On;
    PCFlag:= True;

    writeln;
    Repeat
        Repeat
            write(' Number of nodes/port calls, in route (< ',
                 '1+MaxPrtCl,': '));
            readln(Sd);
            Val(Sd, NrPortCl, e);
            Until (e = 0);
            Until ((NrPortCl <= 30) and (NrPortCl > 0));

        for i:=1 to MaxPrtCl do
            PortName[i]:=‘XXXXX’;

        writeln;
    end;
end;
for i:=1 to NrPortCl do
    begin
        writeln;
        write(' Port name at node ',i,' (< 6 letters e.g. USNYC) : ');
        readln(PortName[i]);
        Erase_White5(PortName[i]); { ELIMINATES ALL SPACES ' ' }
        BumpStrUp5(PortName[i]);
    end;
end; { PROCEDURE Port_Names }

{ ----------------------------------------------- }

procedure Depreciation_Input(
    var FishDepn  : extended;
    var NrODmkts : integer;
    var PrcFresh : LinkcrX);

{ READS IN PERISHABILITY DATA FROM KEYBOARD (CMND 4 IN SUBMENU) }

var i, e: integer;
    Sd: String[20];
begin
    ClrScr;
    Cursor_On;
    PGFlag:= True;
    writeln;
    Repeat
        Repeat
            write(' Percent value depreciation of perishables per day: ');
            readln(Sd);
            Val(Sd, FishDepn, e);
            Until (e = 0);
        Until (FishDepn >= 0);
    for i:=1 to MaxLnks do
        PrcFresh[i]:=0;
    for i:=1 to NrODmkts do
        begin
            writeln;
            Repeat
                write(' Percent of perishables of total cargo',
                    ' in O-D market ',i,' : ');
                readln(Sd);
                Val(Sd, PrcFresh[i], e);
                Until (e = 0);
            Until (PrcFresh[i] >= 0);
        end;
    end; { PROCEDURE Depreciation_Input }
procedure Write_Keyboard_Input_to_File( var Verknafn,
    Inn_Skra : String20;
    var ShipSize : extended;
    var Nlinks,
        NrODmkts,
        NrPortCl : integer;
    var RtData : RtDataX;
    var ODdata : ODdataX;
    var PortName : PrtNameX;
    var FishDepn : extended;
    var PrcFresh : LinkcrX);

{ WRITES ALL SUBMENU/KEYBOARD INPUTS TO A FILE (CMND 5 IN SUBMENU) }

var In_file: text;
i,j: integer;
Ch: char;

begin
    Clean_Menu;
    MenFlag2:= True;

    repeat
        GoToXY(19,13);
        Cursor_On;
        write('Name of file to store input data: '); write('”);
        readln(Inn_Skra);
        Erase_White20(Inn_Skra); { ERASES WHITE (EMPTY) SPACE FROM INPUT }
        Cursor_Off;
        until (Length(InnSkra) > 0); { WAIT UNTIL SOME ANSWER }

    Assign(In_file, Inn_Skra);
    {$I-}
    Rewrite(In_file);
    if (IOResult <> ) then
       begin
            Cursor_On;
            Center(13,'Invalid file name, press any key to continue...');
            { INPUT WAS BAD, RETURN TO SUBMENU }
            Flush_kb_Buffer;
            Ch:= ReadKey;
            Cursor_Off;
            {$I+}
            Exit; { INVALID FILE NAME => EXIT TO MAIN MENU }
       end;
    {$I+}
    Cursor_Off;
{ InputStr TELLS PROGRAM IF INPUT FILE IS A VALID ONE. }
{ InputStr = 'INPUT', MUST BE AT TOP OF INPUT FILE. }
writeln(In_file,'INPUT');

{ WRITE ALL KEYBOARD DATA INTO FILE Inn_Skra WITH 'HANDLE' In_File }
EraseWhite20(VerKNafl);
writeln(In_file,VerKNafl);
writeln(In_file,CargUnit:3);
writeln(In_file,ShipSize:0:0);
writeln(In_file,Nlinks);

for i:= 1 to Nlinks do
begin
  write(In_file,RtData[1,i]:3:0);
  write(In_file,RtData[2,i]:3:0);
  write(In_file,RtData[3,i]:6:0);
  write(In_file,RtData[4,i]:5:0);
  write(In_file,RtData[5,i]:5:0);
  writeln(In_file,RtData[6,i]:7:0);
end;

writeln(In_file,NrODmkts);

for i:=1 to NrODmkts do
begin
  write(In_file,ODdata[1,i]:6:0);
  write(In_file,ODdata[2,i]:6:0);
  write(In_file,ODdata[3,i]:4:0);
  j:=3;
  while ODdata[j,i] <> 0 do
  begin
    j:=j+1;
    if ODdata[j,i] <> 0 then
      write(In_file,ODdata[j,i]:4:0)
    else
      writeln(In_file);
  end;
end;

writeln(In_file,NrPortCl);

for i:=1 to NrPortCl do
writeln(In_file,PortName[i]);

writeln(In_file,FishDepn:2:0);

for i:=1 to NrODmkts do
  writeln(In_file,PrcFresh[i]:3:0);

Close(In_file);
RPFlag:= False; { INPUTS FROM SUBMENU SAVED => PAINT WHITE AGAIN }
ODFlag:= False;
PCFlag:= False;
PGFlag:= False;
end; { PROCEDURE Write_Keyboard_Input_to_File }

{ ----------------------------------------------- }

procedure Input_SubMenu( var CargUnit,
                         Verknafn,
                         Inn_Skra : String20;
var ShipSize : extended;
var Nlinks,
     NrODmkts,
     NrPortCl : integer;
var RtData : RtDataX;
var ODdata : ODdataX;
var PortName : PrtNameX;
var FishDepn : extended;
var PrcFresh : LinkcrX);

var In_file: text;
Ch: char;
i,j: integer;
Run: boolean;

begin
TextColor(White);
TextBackGround(Blue);

Run:= False; { CONTROLS MENU BELOW. IS ALWAYS FALSE }

Repeat
    Draw_Input_Submenu; { DRAWS PICTURE OF INPUT SUB-MENU }
    MenFlag2:=False;
    Flush_KB_Buffer;
    { ELIMINATES "BAD" KEYSTROKES ENTERED BEFORE MENU APPEARS }
    Repeat
        Answer:= UpCase(ReadKey);
    Until (Answer in [ '0', '1', '2', '3', '4', '5' ]);
    Case Answer of
      '0' : begin
            MenuFlag:= True;
            { ONLY REDRAW TEXT IN MAIN MENU, NOT HORIZ. LINES }

            { WIPE OUT YELLOW LETTERS IN SUBMENU }
            RPFlag:= False;
         end;
ODFlag:= False;
PCFlag:= False;
PGFlag:= False;
Exit; { LEAVE TO MAIN MENU }
end;

'1' : Route_Data(CargUnit, Verknafn, ShipSize,NLinks,RtData);
'2' : Origin_Destination_Data(CargUnit, NrODmkts, ODdata);
'3' : Port_Names(NrPortCl, Nlinks, PortName);
'4' : Depreciation_Input(FishDepn, NrODmkts, PrcFresh);
'5' : Write_Keyboard_Input_to_File(Verknafn, Inn_Skra,
Shipsize, Nlinks, NrODmkts, NrPortCl, RtData, ODdata, PortName, FishDepn, PrcFresh);
end; { CASE Answer of }

Until (Run = True); { Run IS NEVER TRUE }
end; { PROCEDURE Input_SubMenu }

{ --------------------------------------------- }
repeat
  GoToXY(23,13);
  Cursor_On;
  write('Name of input file : ');
  readln(Inn_Skra);
  Cursor_Off;
  Erase_White20(Inn_Skra); \{ ERASE WHITE SPACES IF IN INPUT \}
until (Length(Inn_Skra) > 0);

Pass:= True;
MenuFlag:= True; \{ ONLY REDRAW TEXT IN MAIN MENU NEXT TIME \}

Assign(In_file, Inn_Skra);
{$I-}$
Reset(In_file);
if (IOResult <> 0) then
  begin
    Cursor_On;
    Center(13,'File not found, press any key to continue...');
    Flush_KB_Buffer;
    Ch:= ReadKey;
    Cursor_Off;
    {$I+}$
    Pass:= false;
    Exit;
  end;
{$I+}$

{ InputStr TELLS PROGRAM IF INPUT FILE IS A VALID ONE. } 
{ InputStr = 'INPUT', MUST BE AT TOP OF INPUT FILE. } 
readln(In_file, InputStr); \{ READ FIRST LINE/STRING IN INPUT FILE \} 
Erase_White20(InputStr); \{ ERASE WHITE SPACES IF IN STRING \} 
BumpStrUp20(InputStr); \{ MAKE STRING ALL UPPERCASE \} 

{ IF STRING 'INPUT' IS NOT AT TOP OF INPUT FILE, EXIT TO MENU } 
if (InputStr <> 'INPUT') then
  begin
    Cursor_On;
    Center(13,'File not a valid input file, press any key to continue...');
    Flush_KB_Buffer;
    Ch:= ReadKey;
    Cursor_Off;
    {$I+}$
    Pass:= false;
    Exit;
  end;

readln(In_file, VerkNafn);
Erase_White20(VerkNafn); \{ ELIMINATES SPACES FROM STRING \}
readln(In_file, CargUnit);
Erase_White20(CargUnit);
BumpStrUp20(CargUnit);
{ ENSURES THAT CargUnit IS ALL UPPERCASE }
readln(In_file, ShipSize);

for i:=1 to 6 do begin
  for j:=1 to MaxLnks do
    RtData[i,j]:=0;
end;
readln(In_file, Nlinks);
for i:=1 to Nlinks do
  readln(In_file, RtData[1,i], RtData[2,i], RtData[3,i],
         RtData[4,i], RtData[5,i], RtData[6,i]);

for i:=1 to MaxPrtCl do
  begin
    for j:=1 to MaxOD do
      ODdata[i,j]:=0.0;
  end;
readln(In_file, NrODmkts);
for i:=1 to NrODmkts do begin
  read(In_file, ODdata[1,i]);
  read(In_file, ODdata[2,i]);
  j:=3;
  Repeat
    read(In_file, ODdata[j,i]);
    j:=j+1;
  Until Eoln(In_file);
  readln(In_file);
end;

for i:=1 to MaxPrtCl do
  PortName[i]:='XXXXX';
readln(In_file, NrPortCl);
for i:=1 to NrPortCl do begin
  readln(In_file, PortName[i]);
  Erase_White5(PortName[i]);
end;

for i:=1 to MaxLnks do
  PrcFresh[i]:=0.0;
readln(In_file, FishDepn);
for i:=1 to NrODmkts do
  readln(In_file, PrcFresh[i]);

Close(In_file);
end; { procedure Read_from_File }
procedure View_Any_File;

{ VIEW ANY FILE (CMND 5 IN MAIN MENU) }

var s : String[132];
  i : integer;
  Ch : char;
  InFile, OutFile : text;
  Inn_Skra : String20;

begin
  Clean_Menu;

  repeat
    GoToXY(23,13);
    Cursor_On;
    write('Name of file to view: ');
    readln(Inn_Skra);
    Erase_White20(Inn_Skra); { ERASES WHITE (EMPTY) SPACE FROM INPUT }
  until (Length(Inn_Skra) > 0);

  Cursor_Off;

  Assign(InFile, Inn_Skra);
  {$I-}
  Reset(InFile);
  if (IOResult <> 0) then
    begin
      Cursor_On;
      Center(13, 'File not found, press any key to continue...');
      Flush_KB_Buffer;
      Ch := ReadKey;
      Cursor_Off;
      {$I+}
      MenuFlag := True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }
      Exit; { FILE DOES NOT EXIST => EXIT TO MAIN MENU }
    end;
    {$I+}

  Close(InFile);
  Get_Video_Mode('video.cfg');
  Help_File(Inn_Skra, Inn_Skra);

end; { procedure View_Any_File }

{ --------------------------------------------- }
procedure View_Output(var Ut_Skra : String20);

{ VIEW OUTPUT AFTER RUNNING IMPACT (CMND 3 IN MAIN MENU) }

var s : String[132];
i : integer;
Ch : char;
InFile, OutFile : text;

begin
  if (Ut_Skra = 'qweasad') then
  begin
    Clean_Menu;
    Cursor_On;
    Center(13,'No input has been processed yet, press any key...');
    { CENTERS ABOVE MESSAGE ON SCREEN AT LINE 13 }
    Flush_KB_Buffer;
    Ch:= ReadKey;
    Cursor_Off;
    MenuFlag:= True; { ONLY REDRAW TEXT IN MAIN MENU NEXT TIME }
    Exit; { FILE DOES NOT EXIST => EXIT TO MAIN MENU }
  end;

  Get_Video_Mode('video.cfg');
  Help_File(Ut_Skra,'FLEET IMPACT OUTPUT');
end; { procedure View_Output }

{ ----------------------------------------------- }

procedure simpix(var a: RealArrayMPbyNP;
  m,n,m1,m2,m3: integer;
  var icase: integer;
  var izrov: IntegerArrayN;
  var iposv: IntegerArrayM);

{ THIS PROCEDURE SOLVES AN LP WITH THE SIMPLEX METHOD. }
{ SEE BEGINNING OF PROGRAM FOR VARIABLE EXPLANATIONS. }

Label 1,2,3,4,5,99;
const eps = 1.0e-6;

var n12,n11,m12,kp,kh,k,is,ir,ip,i: integer;
  q1,bmax: real;
  11: "IntegerArrayNP;
  12,13: ^IntegerArrayM;
procedure simp1(var a: RealArrayMPbyNP;
   mm: integer;
   var ll: IntegerArrayNP;
   n1l, iabf: integer;
   var kp: integer;
   var bmax: real);
var
   k: integer;
   test: real;
begin
kp := ll[1];
bmax := a[mm+1,kp+1];
for k := 2 to n1l do begin
   if iabf = 0 then
      test := a[mm+1,ll[k]+1]-bmax
   else
      test := abs(a[mm+1,ll[k]+1])-abs(bmax);
   if test > 0.0 then begin
      bmax := a[mm+1,ll[k]+1];
kp := ll[k]
   end
end
end;

procedure simp2(var a: RealArrayMPbyNP;
   m,n: integer;
   var l2: IntegerArrayM;
   n12: integer;
   var ip: integer;
   kp: integer;
   var q1: real);
Label 1,2,99;
const
   eps = 1.0e-6;
var
   k, ii, i: integer;
   qp, q0, q: real;
begin
   ip := 0;
   for i := 1 to n12 do
      if a[l2[i]+1,kp+1] < -eps then GoTo 1;
   GoTo 99;
1: q1 := -a[l2[i]+1,1]/a[l2[i]+1,kp+1];
   ip := l2[i];
   for i := i+1 to n12 do begin
      ii := l2[i];
      if a[ii+1,kp+1] < -eps then begin
         q := -a[ii+1,1]/a[ii+1,kp+1];
         if q < q1 then begin
            ip := ii;
            q1 := q
         end
      end
end
else if q = q1 then begin
  for k := 1 to n do begin
    qp := -a[ip+1,k+1]/a[ip+1,kp+1];
    q0 := -a[ii+1,k+1]/a[ii+1,kp+1];
    if q0 <> qp then GoTo 2
  end;

2: if q0 < qp then ip := ii
end
end

begin
pi := 1.0/a[ip+1,kp+1];
for ii := 1 to i+1 do begin
  if ii-1 <> ip then begin
    a[ii,kp+1] := a[ii,kp+1]*pi;
    for kk := 1 to k+1 do
      if kk-1 <> kp then
        a[ii,kk] := a[ii,kk] -a[ip+1,kk]*a[ii,kp+1]
  end
end;
for kk := 1 to k+1 do
  if kk-1 <> kp then
    a[ip+1,kk] := -a[ip+1,kk]*pi;
  a[ip+1,kp+1] := pi
end;

begin
if m <> m+m2+m3 then begin
  writeln('pause in routine SIMPLX');
  writeln('bad input constraint counts');
  readln
end;
new(l1);
new(l2);
new(l3);
n11 := n;
for k := 1 to n do begin
  l1[k] := k;
  izroV[k] := k
end;

n12 := m;
for i := 1 to m do begin
  if a[i+1,1] < 0.0 then begin

end;
writeln('pause in routine SIMPLX');
writeln('bad input tableau');
readln
end;

12^[i] := i;
iposv[i] := n+i
end;

for i := 1 to m2 do 13^[i] := 1;
ir := 0;
if m2+m3 = 0 then
  GoTo 5;
ir := 1;
for k := 1 to n+1 do begin
  ql := 0.0;
  for i := ml+1 to m do
    ql := ql + a[i+1,k];
a[m+2,k] := -ql
end;

3: simpl(a,m+l,1l^,n1l,0,kp,bmax);
if (bmax <= eps) and (a[m+2,1] < -eps) then begin
  icase := -1;
  GoTo 99
end
else if (bmax <= eps)
  and (a[m+2,1] <= eps) then begin
  m12 := ml+m2+1;
  if m12 <= m then begin
    for ip := m12 to m do begin
      if iposv[ip] = ip+n then begin
        simpl(a,ip,1l^,n1l,1,kp,bmax);
        if bmax > 0.0 then GoTo 1
      end
    end
  end;
  ir := 0;
m12 := m12-1;
if ml+1 > m12 then GoTo 5;
for i := ml+1 to m12 do
  if 13^[i-ml] = 1 then
    for k := 1 to n+l do a[i+1,k] := -a[i+1,k];
  GoTo 5
end;
simp2(a,m,n,12^,nl2,ip,kp,ql);
if ip = 0 then begin
  icase := -1;
  GoTo 99
end;

1: simp3(a,m+l,n,ip,kp);
if iposv[ip] >= n+ml+m2+1 then begin
  for k := 1 to nl1 do
    if 1l^[k] = kp then GoTo 2;
2: nl1 := nl1-1;
for is := k to nil do 11^[is] := 11^[is+1]
end
else begin
  if iposv[ip] < n+ml+1 then GoTo 4;
  kh := iposv[ip]-ml-n;
  if 13^[kh] = 0 then GoTo 4;
  13^[kh] := 0
end;
a[m+2,kp+1] := a[m+2,kp+1]+1.0;
for i := 1 to m+2 do a[i,kp+1] := -a[i,kp+1];
4: is := izrov[kp];
  izrov[kp] := iposv[ip];
  iposv[ip] := is;
  if ir <> 0 then
    GoTo 3;
5: simp1(a,0,11,n11,0,kp,bmax);
if bmax <= 0.0 then begin
  icase := 0;
  GoTo 99
end;
  simp2(a,m,n,12,n12,ip,kp,ql);
if ip = 0 then begin
  icase := 1;
  GoTo 99
end;
simp3(a,m,n,ip,kp); GoTo 4;
99: dispose(13);
dispose(12);
dispose(11)
end;

{ ----------------------------------------------- }

procedure Cargo_per_Link( var  RtData : RtDataX;
var ODdata : ODdataX;
var Linkcrgo : LinkcrX;
var Nlinks : integer;
var FltMgnOD : LinkcrX);

{ SECOND PART OF CMD 2 IN MAIN MENU }

var i, j, k : integer;
  Fyrri, Seinni: extended;

begin
  for i:=1 to MaxLnks do
    Linkcrgo[i] := 0;
for k:=1 to Nlinks do
  begin
    Fyrri:= RtData[1,k];
    Seinni:= RtData[2,k];

    for i:=1 to NrODmkts do
      begin
        for j:=3 to (MaxPrtCl-1) do
          begin
            if ((Fyrri = ODdata[j,i]) and
                (Seinni = ODdata[j+1,i]))
              then
                Linkcrgo[k]:=Linkcrgo[k] + FltMgnOD[i];
          end;
      end;
  end; { procedure Cargo_per_Link }

{ ----------------------------------------------- }

procedure AvailContaMiles( var ACM,
                          RCM_SW,
                          RCD_SW,
                          LF_SW : extended;
                          var NLinks : integer;
                          var RtLength,
                          ShipSize : extended;
                          var RtData : RtDataX;
                          var RCM,
                          RCD,
                          RCDOD,
                          LF_link,
                          FltMgnOD : LinkcrgoX);

{ THIRD PART OF CMND 2 IN MAIN MENU }

var i,j,k: integer;
  Fyrri, Seinni, Nrl, Nr2: extended;

begin
  ACM:= RtLength * ShipSize;
  RCM_SW:= 0;
  for i:=1 to Nlinks do
    begin
      RCM[i]:= Linkcrgo[i] * RtData[6,i];
      RCM_SW:= RCM_SW + RCM[i];
    end;
RCD_SW:= 0;
for i:=1 to Nlinks do
begin
  RCD[i]:= Linkcrgo[i]*(0.5*(RtData[4,i] + RtData[5,i])
            + RtData[3,i]) / 24.0;
  RCD_SW:= RCD_SW + RCD[i];
end;

LF_SW:= RCM_SW / ACM;
for i:=1 to Nlinks do
  LF_link[i]:= Linkcrgo[i] / ShipSize;

for i:=1 to NrODmkts do
  RCD_OD[i]:= 0.0;

for i:=1 to NrODmkts do
begin
  for j:=3 to (MaxOD-1) do
  begin
    Fyrri:= ODdata[j,i];
    Seinni:= ODdata[j+1,i];
    if (Seinni <> 0.0) then
      begin
        for k:=1 to Nlinks do
        begin
          Nr1:= RtData[1,k];
          Nr2:= RtData[2,k];
          if (Nr1 = Fyrri) then
            begin
              RCD_OD[i]:= RCD_OD[i]
                      + ((0.5*(RtData[4,k]+RtData[5,k])
                          + RtData[3,k]) / 24.0)*FltMgnOD[i];
            end;
        end;
      end;
  end;
end; { procedure Avail_Cnt_Miles }

{ ---------------------------------- }

procedure Write_to_File(var CargUnit,
                         Verknafn,
                         Ut_Skra : String20;
                         var ShipSize,
                         RtLength : extended;
                         var Nlinks,
                         NrODmkts,
                         NrPortCl1 : integer;
                         var RtData : RtDataX;
                         var ODdata : ODdataX;
                         var PortName : PrtNameX;
var ACM, RCM_SW, RCD_SW, LF_SW : extended;
var Inn_Skra : String20;
var RCM, RCD, RCD_OD, LF_Link : LinkcrX;
var FishDepn : extended;
var PrcFresh, ODdepn, Linkcrgo : LinkcrX);

{ FOURTH AND LAST PART OF CMND 2 IN MAIN MENU }
{ WRITES OUTPUT TO FILE AND DOES SOME CALCULATIONS }

var i, j, k, l, NumbPrts: integer;
Out_file : text;
Year,Month,Day,DOW,Hour,Minute,Second,Hundreth : word;
Ports : array[1..MaxLnks] of string;
String1, String2, PortPair: string;
Fyrra, Seinna: integer;
First, TotprcDp, SecondD, TotDepn, TotCargo: extended;
Ch: char;
Fyrri, Seinni, RtTime: real;

{ PROCEDURE Simp1x INPUTS/OUTPUTS FOLLOW }
mm,nn,ml,m2,m3: integer; { ERROR HANDLING FLAG FOR PROCEDURE Simp1x }
izrov: IntegerArrayN;
{ SUBSCRIPTS OF DECISION VARIABLES THAT ARE NOT PART OF THE }
{ SOLUTION BASIS. IF iposv[k] (SUBSCR.) > NrODmkts THEN }
{ IT IS A SLACK VARIABLE }

iposv: IntegerArrayM;
{ SUBSCRIPTS OF DECISION VARIABLES THAT ARE PART OF THE }
{ SOLUTION BASIS. IF iposv[k] (SUBSCR.) > NrODmkts THEN }
{ IT IS A SLACK VARIABLE }

ASkra: text;
FltMgnOD: LinkcrX; { FREIGHT TO CARRY IN EACH O-D AT LP OPTIMUM }
Spill: real; { TOTAL (ROUTE) SPILL AT OPTIMUM }

begin

repeat
GoToXY(23,13);
ClrEoL;
Cursor_On;
write('Name of output file : ');
readln(Ut_Skra);
Erase_White20(Ut_Skra); { ERASES WHITE SPACES IF ENTERED }
Cursor_Off;
until (Length(Ut_Skra) > 0);
Cursor_Off;
Assign(Out_file, Ut_Skra);
{$I-}
Rewrite(Out_file);
if (IOResult <> 0) then
begin
    Cursor_On;
    Center(13,'Invalid output file, press any key to continue...');
    { CENTERS MESSAGE ABOVE ON SCREEN AT LINE 13 }
    Flush_KB_Buffer;
    Ch:= ReadKey;
    Cursor_Off;
{$I+}
    Exit; { INVALID/BAD FILE NAME => EXIT TO MAIN MENU }
end;
{$I+}
writeln(Out_file);
writeln(Out_file,' **********************************************',
    '*****************************************************************************');
writeln(Out_file,' ***',*':67);
writeln(Out_file,' ***', 'FLEET IMPACT':38,'***':29);
writeln(Out_file,' ***',*':67);
writeln(Out_file,' ***','Optimization Software for Fleet Planning':53,'***':14);
writeln(Out_file,' ***',*':67);
writeln(Out_file,' ***','Copyright (C) 1994 Viglundur T. Viglundsson':56,'***':11);
writeln(Out_file,' ***',*':67);
writeln(Out_file,' ***','----------------------------------------------------------');
writeln(Out_file);        
writeln(Out_file);
GetTime(Hour,Minute,Second,Hundreth);
for i:= 1 to 23 do
    writeln(Out_file, ' ');  
writeln(Out_file,' Time: ',Hour,' :',Minute,' :',Second);
GetDate(Year,Month,Day,DOW);
for i:= 1 to 23 do
    writeln(Out_file, ' ');  
writeln(Out_file,' Date: ',Day,' .',Month,' .',Year);
for i:= 1 to 23 do
    writeln(Out_file, ' ');  
writeln(Out_file,' Route name: "',VerkNafn,'"');
for i:= 1 to 23 do
  write(Out_file,' ');
BumpStrUp20(Inn_Skra);
writeln(Out_file,' Input file is: ', Inn_Skra);
for i:= 1 to 23 do
  write(Out_file,' ');
BumpStrUp20(Ut_Skra);
writeln(Out_file,' This file is: ', Ut_Skra);

writeln(Out_file);
writeln(Out_file);

writeln(Out_file,' ******************************************',
  '******  INPUT DATA  *********************************');

RtLength:= 0;
for i:=1 to Nlinks do
  RtLength:= RtLength + RtData[6,i];

RtTime:= 0;
for i:=1 to Nlinks do
  for j:=3 to 4 do
    RtTime:= RtTime + RtData[j,i];
    { TIME THAT IT TAKES SHIP TO GO ONE ROUTE CYCLE }

writeln(Out_file);
writeln(Out_file,' Ship capacity: ',Shipsize:0:0,
  ' ',CargUnit,'s');
writeln(Out_file,' Length of route cycle: ',RtLength:0:0);
writeln(Out_file,' Route cycle time (hrs/days): ',
  RtTime:0:0,'/',RtTime/24:0:1);
writeln(Out_file,' Nr. of route links: ',Nlinks:2);
writeln(Out_file,' Nr. of O-D markets: ',NrODmks:2);
writeln(Out_file,' Nr. of port calls: ',NrPortCl:2);
writeln(Out_file);
writeln(Out_file);

for i:=1 to Nlinks do
  begin
    Fyrra:= Round(RtData[1,i]);
    Seinna:= Round(RtData[2,i]);
    for j:=1 to NrPortCl do
      begin
        String1 := PortName[Fyrra];
        String2 := PortName[Seinna];
        end;
    Ports[i] := concat(String1,'-',String2);
  end;

writeln(Out_file,' ROUTE DATA:');
writeln(Out_file,' ==================================================');
writeln(Out_file, 'Port Second', ':15);
writeln(Out_file, 'Link# pair time port time', 'Distance |');
writeln(Out_file, 'I');
for i:=1 to NLinks do
  writeln(Out_file, ' ', i:4, ', Ports[i]:12, ', RtData[3,i]:5:0,
  ', ', RtData[4,i]:5:0, ', ', RtData[5,i]:5:0,
  ', ', RtData[6,i]:7:0', '|':5);
writeln(Out_file, 'I');
writeln(Out_file);
writeln(Out_file, 'FREIGHT DATA:');
writeln(Out_file, 'I');
writeln(Out_file, 'I');
writeln(Out_file, 'O-D mkt Origin/Dest.', 'Avail. Freight (', 'CargUnit, 's |');
writeln(Out_file, 'I');
for i:=1 to NrODmktks do
  begin
    First:= ODdata[3,i];
    for k:=4 to MaxOD do
      if ODdata[k,i] <> 0 then SecondD:= ODdata[k,i];
    String1 := PortName[Round(First)];
    String2 := PortName[Round(SecondD)];
    Portpair:= concat(String1, '/', String2);
    Str(First:3:0,String1);
    Str(SecondD:2:0,String2);
    String1:= Concat(String1, ' -', String2);
    writeln(Out_file, ' ', String1, ' ', Portpair:13,
    ', ', ODdata[1,i]:11:0, '|':12);
  end;
writeln(Out_file, 'I');
writeln(Out_file, 'I');
writeln(Out_file, 'I');
writeln(Out_file, '***** OUTPUT DATA ***********');
writeln(Out_file, '***** OUTPUT DATA ***********');
{ FILL UP a MATRIX FOR SIMPLEX }
for k:=1 to Nlinks do
begin
  Fyrri:= RtData[1,k];
  Seinni:= RtData[2,k];

for i:=1 to NrODmkts do
begin
  First:= ODdata[3,i];
  for l:=4 to MaxOD do
    if ODdata[1,i] <> 0
      then SecondD:= ODdata[1,i];
  for j:=3 to (MaxPrtCl-1) do
    begin
      if ((Fyrri = ODdata[j,i]) and
           (Seinni = ODdata[j+l,i]))
        then
          a[k+l,i+l]:= -1; { FILLS UP a MATRIX FOR SIMPLEX }
    end;
end; { CONSTRAINTS ON EACH LINK USED BY MANY O-D MARKETS }
end;

{ NET FREIGHT REVENUE NUMBERS FROM INPUT FILE }
for j:=2 to (NrODmkts+l) do
  a[1,j]:= ODdata[2,j-1];
a[1,1]:=0; { ALWAYS ZERO BEFORE Simp1x IS RUN }
for i:= (Nlinks+2) to (Nlinks+NrODmkts+l) do
  a[i,i-Nlinks]:= -1; { DIAGONAL PART OF a MATRIX (CONSTRAINT ON
                      AVAIL. FREIGHT PER O-D) }
for i:=2 to (Nlinks+l) do
  a[i,1]:=ShipSize; { LINK CAPACITY LIMITED BY SHIP SIZE }
for i:=(Nlinks+2) to (Nlinks+NrODmkts+l) do
  a[i,1]:= ODdata[1,i-Nlinks-1];
{ AVAILABLE FREIGHT IN EACH O-D MARKET }
for i:=1 to n do
  izrov[i]:=0;
for i:=1 to m do
  iposv[i]:=0;
nn:= NrODmkts; { NUMBER OF DECISION VARIABLES: N }
ml:= Nlinks + NrODmkts; { NUMBER OF <= CONSTRAINTS, bi > 0 }
m2:=0; { NUMBER OF >= CONSTRAINTS, bj > 0 }
m3:=0; { NUMBER OF = CONSTRAINTS, bk > 0 }
mm:= ml + m2 + m3; { TOTAL NUMBER OF CONSTRAINTS: M }
Simplx(a,mm,nn,m1,m2,m3,icase,izrov,iposv);
{ SOLVE LP WITH SIMPLEX METHOD }

for i:=1 to NrODmkts do
FltMgnOD[i]:=0;

for i:=1 to (Nlinks+NrODmkts) do
  { IF BASIS VARIABLE IS NOT SLACK }
    if iposv[i] <= NrODmkts then
      FltMgnOD[(iposv[i])]:= a[i+1,1];

Spill:= 0;
for i:=1 to NrODmkts do  { TOTAL (ROUTE) SPILL }
  Spill:= Spill + ODdata[1,i] - FltMgnOD[i];

writeln(Outfile);
writeln(Outfile);
writeln(Outfile,'
LinE1AR PROGRAM (LP) OUTPUTS:');
writeln(Outfile);
writeln(Outfile,' Total spill at LP optimum is: ','Spill:5:0',',CargUnit','s');
writeln(Outfile,' Total net freight revenues at LP optimum are: ','a[1,1]:7:0');
writeln(Outfile);
writeln(Outfile);
 writeln(Out_file,' LINEAR PROGRAM (LP) OUTPUTS:');
 writeln(Out_file,' LP RESULTS. FREIGHT TO CARRY IN EACH O-D (',
                  'CargUnit','s):');
 writeln(Out_file,'O-D mkt Origin/Dest. Avail.Frt.',
                'To carry Spill |');
 writeln(Out_file,'');

for i:=1 to NrODmkts do
  First:= ODdata[3,i];
  for k:=4 to MaxOD do
    if ODdata[k,i] <> 0
    then
      SecondD:= ODdata[k,i];
      String1 := PortName[Round(First)];
      String2 := PortName[Round(SecondD)];
      Str(First:3:0,String1);
      Str(SecondD:2:0,String2);
      String1:= Concat(String1,' - ',String2);
      if (ODdata[1,i] = FltMgnOD[i]) then
        { WRITE ALL IN COLUMN }
        writeln(Out_file,' Portpair:13,',
               ',ODdata[1,i]:9:0,'ALL':12,
               (ODdata[1,i]-FltMgnOD[i]):10:0,' |':'3)
else
  writeln(Out_file,' | ',String1,' | ',Portpair:13,
         ' | ',ODdata[1,i]:9:0,FltMgnOD[i]:12:0,
         (ODdata[1,i]-FltMgnOD[i]):10:0,' | ':3);

end;

writeln(Out_file,' -----------------------------------------',
        ' -----------------------------------------');

Cargo_per_Link(RtData, ODdata, Linkcrgo, Nlinks,FltMgnOD);

AvailContaMiles(ACM, RCM SW, RCD SW, LF SW,
                 Nlinks, RtLength, ShipSize, RtData, RCM,
                 RCD, RCD OD, LF link, FltMgnOD);

writeln(Out_file);
writeln(Out_file);
writeln(Out_file,' SYSTEM-WIDE OUTPUTS:');
writeln(Out_file);
if CargUnit = 'TEU' then
  begin
    writeln(Out_file,' Available Container-Miles (ACMs): ',ACM:8:0);
    writeln(Out_file,' Revenue Container-Days (RCDs): ',RCD_SW:11:0);
    writeln(Out_file,' Revenue Container-Miles (RCMs): ',RCM_SW:10:0);
    writeln(Out_file,' Average Load Factor (ALF): ',
                    100*LF_SW:14:1,'%');
  end
else
  begin
    writeln(Out_file,' Available Ton-Miles (ATMs): ',ACM:9:0);
    writeln(Out_file,' Revenue Ton-Days (RTDs): ',RCD_SW:12:0);
    writeln(Out_file,' Revenue Ton-Miles (RTMs): ',RCD_SW:11:0);
    writeln(Out_file,' Average Load Factor (ALF): ',
                    100*LF_SW:10:1,'%');
  end;

writeln(Out_file);
writeln(Out_file);
writeln(Out_file,' ROUTE LINK OUTPUTS:');
writeln(Out_file,' | Link# Port pair RCDs LF (%) | ',RCDs,' LF (%) | ',RCDs,' LF (%) | ',RCDs,' LF (%) | ');
begin
  writeln(Out_file, '    | Link#  Port pair  RTM',
           '             RTDs   LF (%) |
  writeln(Out_file, __________________________|
  end;

for i:=1 to NLinks do
  writeln(Out_file, ',i:4, ', Ports[i]:13, ',RCM[i]:12:0,',
           RCD[i]:12:0, ',100 * LF_link[i]:5:1,'
  writeln(Out_file, __________________________|

writeln(Out_file);
writeln(Out_file);
if CargUnit = 'TEU' then begin
  writeln(Out_file, 'REVENUE CONTAINER-DAYS (RCD) BY O-D MARKET:');
  writeln(Out_file, __________________________|
  writeln(Out_file, 'O-D market Origin/Dest. RCDs ')
  writeln(Out_file, __________________________|
end
else begin
  writeln(Out_file, 'REVENUE TON-DAYS (RTD) BY O-D MARKET:');
  writeln(Out_file, __________________________|
  writeln(Out_file, 'O-D market Origin/Dest. RTDs ')
  writeln(Out_file, __________________________|
end;

for i:=1 to NrODmktks do begin
  First:= ODdata[3,i];
  for k:=4 to MaxOD do
    if ODdata[k,i] <> 0 then SecondD:= ODdata[k,i];
  String1 := PortName[Round(First)];
  String2 := PortName[Round(SecondD)];
  Portpair:= concat(String1,'/',String2);
  Str(First:3:O,String1);
  Str(SecondD:2:O,String2);
  String1:= Concat(String1,' -',String2);
  writeln(Out_file, ',',Portpair:17,' ',
           RCD_OD[i]:11:0,' ')
end;
TotDepn:=0;
TotCargo:=0;
TotprcDp:=0;
for i:=1 to NrODmkts do
  ODdepn[i]:=0;
for i:=1 to NrODmkts do
  begin
    TotCargo:= TotCargo + (FltMgnOD[i]*PrcFresh[i]/100);
    ODdepn[i]:= RCD_OD[i] * PrcFresh[i] * FishDepn/10000;
    TotDepn:= TotDepn + ODdepn[i];
  end;

If (TotCargo <> ) then
  TotprcDp:= TotDepn / TotCargo;

writeln(Outfile);writeln(Outfile);
writeln(Outfile);
writeln(Outfile);
writeln(Outfile, ' PERISHABLES DEPRECIATION ANALYSIS:');
writeln(Outfile, ' Deprec. per day: ',FishDepn:6:1,'%');
writeln(Outfile, ' System-wide loss: ',100*TotprcDp:5:1,'%');
writeln(Outfile, ' Total Perishable Cargo: ',TotCargo:0:0,' ',CargUnit,'s');

writeln(Outfile);
writeln(Outfile);
writeln(Outfile, ' PERISHABLES VALUE DEPR. BY O-D MARKET:');
writeln(Outfile, | O-D mkt    Origin/Dest.    Perish. Carried', Depr. (% of value) |');
writeln(Outfile, | ');for i:=1 to NrODmkts do
  begin
    First:= ODdata[3,i];
    for k:=4 to MaxOD do
      if ODdata[k,i] <> 0
        then SecondD:= ODdata[k,i];
    Stringl := PortName[Round(First)];
    String2 := PortName[Round(SecondD)];
    Portpair:= concat(Stringl,'/',String2);
    Str(First:3:0,Stringl);
    Str(SecondD:2:0,String2);
    Stringl:= Concat(Stringl,' -',String2);
    if ((PrcFresh[i] = 0) or (FltMgnOD[i] = 0)) then
writeln(Out_file,' ',String1,' ',Portpair:13,
' ',0:11,' ',0:12,'|':13)
else
  writeln(Out_file,' ',String1,' ',Portpair:13,
' ',PrcFresh[i]/100*FltMgnOD[i]:11:1,' ',
100*ODdepn[i]/(PrcFresh[i]/100*FltMgnOD[i]):12:1,
' |':13);
end;
writeln(Out_file,' ',String1,' ',Portpair:13,
' ',PrcFresh[i]/100*FltMgnOD[i]:11:1,
100*ODdepn[i]/(PrcFresh[i]/100*FltMgnOD[i]):12:1,
' |':13);

writeln(Out_file,' ________________','
',______________');
writeln(Out_file);
writeln(Out_file);
writeln(Out_file,' ***************
',** END OF FLEET IMPACT **********************');
Close(Out_file);
end; { procedure Write_to_File }

{ -------------------------------------------------- }

begin { MAIN PROGRAM }
  MenuFlag:= False; { REDRAW WHOLE MAIN MENU NEXT TIME }

  { FOLLOWING ARE FLAGS FOR INPUTS (GRAY LETTERS) IN SUBMENU }
  RPFlag:= False;
  ODFlag:= False;
  PCFlag:= False;
  PGFlag:= False;

  NrODmkts := 0;
  NrPortCl := 0;
  NLinks := 0;
  FishDepn := 0;
  Flag := False;
  VerkNafn := 'This_is_a_Bad_File';
  CargUnit := 'TEU';
  Shipsize := 1;

  Pictures(Flag);

  for i:=1 to mp do
    for j:=1 to np do
      a[i,j] := 0; { ZEROS IN ALL OF A MATRIX FOR SIMPLEX (LP) METHOD }

  Run := False; { CONTROLS MENU BELOW. IS ALWAYS FALSE }
  Ut_Skra := 'qweasad';
  { DUMMY VALUE, CHANGES IF COMMAND 2 IS RUN }
Repeat
  Draw_Main_Menu;
  100 : Flush_KB_Buffer; { ELIMINATES "BAD" KEYSTROKES } 
Repeat
  Answer:= UpCase(ReadKey);
  Until (Answer in ['0','1','2','3','4','5','6']);

Case Answer of 
 '0' : begin
  Are_You_Sure;
  GoToXY(3,24);
  ClrEol;
  { WIPE OUT LINE THAT SAYS 'REALLY WANT TO QUIT ?'
  BECAUSE THE USER IS NOT QUITTING } 
  Goto 100; { NO MENU REFRESH => NO FLICKER }
end;

'1' : begin
  MenFlag2:= True;
  Input_SubMenu(CargUnit, Verknafn, Inn_Skra, Shipsize, 
  Nlinks, NrODmkts, NrPortCl, RtData, ODdata, 
  PortName, FishDepn, PrcFresh);
end;

'2' : begin { Run Fleet Impact LP processor}
  Read_from_File(CargUnit, Verknafn, Inn_Skra, Shipsize, 
  Nlinks, NrODmkts, NrPortCl, RtData, ODdata, 
  PortName, FishDepn, PrcFresh, Pass);
  if Pass=true then { IF VALID INPUT FILE... }
  Write_to_File(CargUnit, Verknafn, Ut_Skra, 
  Shipsize, RtLength, Nlinks, NrODmkts, NrPortCl, 
  RtData, ODdata, PortName, ACM, RCM_SW, RCD_SW, 
  LF_SW, Inn_Skra, RCM, RCD, RCD_OD, LF_link, 
  FishDepn, PrcFresh, ODdepn, Linkcrgo);
end; { begin '2' }

'3' : View_Output(Ut_Skra);

'4' : Print_Output(Ut_Skra);

'5' : ViewAnyFile;

'6' : begin
  Get_Video_Mode('video.cfg');
  Help_File('help.dat','Help for Fleet Impact');
end; { CASE Answer of }

Until (Run = True);
  { Run IS NEVER TRUE. PROGRAM QUITS WITH Halt COMMAND }
end.