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SHIPCOST: Vessel and Voyage Costing Model

John Arnold, Jr.,¹ and George Panagakos¹

The paper describes SHIPCOST, a computer-based method developed first in 1984 by the World Bank, and subsequently refined, to evaluate vessel and voyage costs. The economics of vessel ownership and operation are examined and examples given of typical fleet voyage and trade costs, including a comparison between the use of newbuildings and secondhand ships. The separate fleet, ship and voyage modules included in the SHIPCOST model are discussed and typical applications given.

1. Introduction

THE DETERMINATION of vessel costs involves the consideration of a range of issues. Some of the most fundamental work on the subject was by Zannetos in 1966, who looked specifically at tankers [1].² More recently Jansson and Shneerson made important contributions to liner shipping economics [2]. In between these two came our own efforts, which cover a broader range of vessels, but are still focused on the way in which the market values vessels.

SHIPCOST is a methodology and a computer-based model for the evaluating vessel and voyage costs. It was developed in 1984 for use by the World Bank staff and its borrowing countries in performing financial and economic appraisals of projects related to maritime ports and shipping. SHIPCOST was prepared as part of a continuing effort which dates back to 1972 when consultants were contracted to prepare a report on the capital and operating costs of various types and sizes of vessels. Subsequent reports of the same nature were prepared in 1976 and 1980.³ While the data provided in these reports were widely used by the Bank staff, they had certain limitations, namely:

- (i) the data were not easily updated,
- (ii) the conditions of the market for shipping services were ignored, and
- (iii) the vessel configurations examined were very limited in number.

SHIPCOST was designed so as to remedy these drawbacks.

The purpose of the paper is to provide a synopsis of the model, to outline the theory behind it, and to present some of its applications. The following two sections present the theoretical basis for the model—the relationship between the costs to the owner of operating a vessel and the costs to the user of maritime transportation. Section 4 describes how the model represents costs. Section 5 elaborates on the general model structure, its inputs and outputs, and its applications in maritime port and shipping projects.

2. Economics of vessel ownership and operation

The cost of a vessel depends upon your point of view. From the owner's perspective, vessel costs include the costs for purchase of the vessel, for the wages and benefits of the crew, for the fuel at sea and in port and for the operating and administrative overheads. From the shipper's point of view, the cost of a vessel is the price paid for use of the vessel whether it be the charter rate or the freight tariff less rebate.

Each shipping company has its own method of accounting for vessel costs. These are determined by the accounting practices and tax regulations of the country in which the company is incorporated. In addition, the vessel owner may use a separate method of accounting for vessel operating costs and for making decisions about the profitability of alternative uses of the vessel.

The cost of marine transportation to the shipper is determined in the marketplace. The supplier attempts to earn a return on his investment and the purchaser tries to obtain an acceptable level of service at minimum cost. Clearly, the cost of construction and operation will affect the price for marine transportation, but the conditions in the market will have an equally important impact. It is the relationship between the two which forms the conceptual basis for our model. Let us now consider how this market works.

If we begin with the simplest situation, we might imagine that all vessels of a specific class compete on a single route. Because of differences in age, crew size, type of propulsion, these vessels would have operating costs which vary as shown in Fig. 1. In this graph, the vessel operating costs are shown for the entire fleet, beginning with the least-cost vessel and concluding with the highest-cost vessel. In terms of classical economics, the price set by the market for transporting a volume of cargo V_0 (in ton-miles) would be C_0 (in \$/ton-mile). In this situation, all vessels with operating costs less than C_0 would be employed. The vessels with operating costs well below C_0 would operate with a considerable surplus. Vessels with operating costs above C_0 would not be employed.

How exactly are these operating costs defined? Clearly these costs would include all avoidable costs such as fuel costs, crew costs,⁴ and variable management costs. Would the operating costs include capital costs? No, because the owner of a vessel would continue to operate rather than lay up his vessel if the price in the market covered his avoidable costs.

As the demand increases to V_1 , additional vessels will be employed on the route. These vessels will have higher operating costs and this will push the market price up to C_1 . If

⁴ Assuming the crew does not have to be paid if the vessel is not being operated.

¹ The World Bank, Washington, D.C.

² Numbers in brackets designate References at end of paper.

³ Previous reports were prepared by Appledore and Microconsultants.

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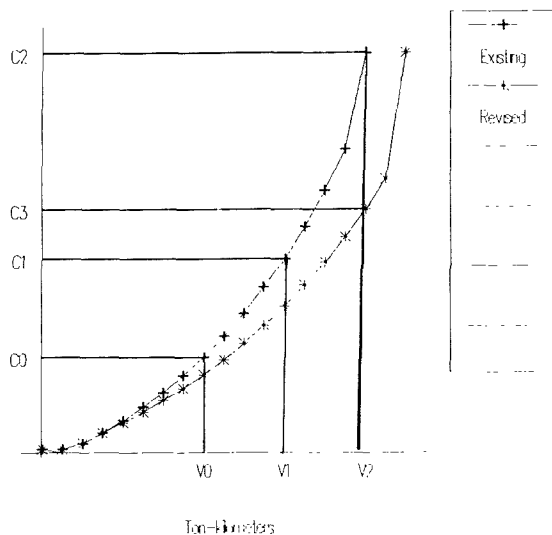


Fig. 1 Vessel fleet short-run marginal costs

the demand increases further, then the available fleet will be fully employed and new vessels will have to be built. In this case, the market price would rise to a level where one or more companies would be willing to purchase new vessels with the expectation that the rates will remain in effect long enough to recover the capital costs after paying all variable costs. This point is shown as C in Fig. 1.

If, while the market waits for the newbuildings to be delivered, the volume of traffic continues to rise, then the price will rise above C_2 as the available capacity is rationed among those willing to pay the highest price. This increase will cause additional investors to contract for new vessels. Once the newbuildings are delivered, the fleet operating cost curve will move to the right as shown in Fig. 1 and the price will moderate. If too many investors were tempted into the market, or if the demand should fall slightly, then the market price could easily fall below C_2 and the more optimistic investors would be unable to recover their capital costs.

So far we have assumed a single route and a single class of vessels. If we broaden the argument to include many different routes, the results would be the same. If each route is served by more than one class of vessels and these vessels can easily be transferred from one route to another, then the extreme movements in price would occur only when the overall demand exceeds the overall supply.

The preceding sequence of events is familiar to those who operate in the charter market, but what about the liner market? In the liner market, the shipping conferences operate according to monopolistic principles. They constrain the supply of transport so as to insure the maximum profit to the shipowners. Although this discipline has been difficult to enforce, most conferences have tried to regulate the supply to the extent that the highest cost operator will earn enough to pay all operating costs and to cover the capital costs for their vessel and the fixed costs for vessel management. The failure of the conferences to achieve this less ambitious goal on the major Atlantic and Pacific routes has been obvious over the last decade.

3. Newbuilding versus resale vessel costs

Most transportation studies are concerned with the cost of supplying transportation under the assumption that the prices for transport in a competitive market will be in line with the costs. In the past, most transportation studies have estimated vessel costs by taking the operating costs of a new-

building and adding the capital costs amortized over its expected life. While this approach might be justified in a situation where a specialized vessel is being introduced to serve a new trade, it is hard to justify the approach in a competitive market.

How should we allow for the effects of changes in supply and demand when making long-term investment plans which require the use of marine transportation? Let us return to the marketplace for a clue, specifically the secondhand market. The buildup of capacity in all types of vessels in the last decade has resulted in a relatively active secondhand market not only for tankers and bulkers, but also for break-bulk and container vessels.

How does the secondhand market set its price? The purchaser is looking for a vessel which, when employed, will earn sufficient revenue to cover its operating costs and to pay for the purchase price. His assessment must take into account the time value of money. Therefore, the basis for setting the price is the discounted value of the expected net cash flow over the remaining life of the vessel. While the resale market cannot provide perfect information about the future, it does reflect the collective wisdom of the buyers and sellers in that market. Where the market is active, with many buyers and sellers, it offers a very useful estimate of the price for marine transportation.

Despite the appeal of the resale market's assessment of the future cost of marine transportation over the medium term, there remains a nagging desire to return to the comfort of the newbuilding cost. This desire is buttressed by the argument that eventually the vessels in the fleet must be replaced. Therefore, in the long run, the marginal vessel must be obtained through construction. While the concept of long-run marginal costs is well established, the use of newbuilding costs to estimate this value has three weaknesses.

First, new vessels have very different cost structures from the typical vessel in the fleet. Their higher capital costs are compensated for by lower operating costs due to automation, more efficient propulsion systems, and better-utilized cargo storage. When estimating marine transportation costs based on new vessels, it is necessary to include these savings in the operating costs.

Second, the newbuilding costs themselves fluctuate with demand. In the last decade, there has been a considerable shakeout in the shipbuilding industry. Less efficient yards have been closed. Korea, with its lower labor costs and access to modern technology, has emerged as the price setter. During the same period, ship construction costs have declined in real terms in all but very specialized markets. In periods of peak demand, when construction capacity is stretched and delays increase, the price of newbuildings will rise as less efficient yards are employed and new vessels are constructed on a fast-track schedule. Thus the short-term cycle in the rates will cause complementary fluctuations in newbuilding costs.

Third, during periods of excess capacity the principal source of vessels is the secondhand market. The newbuilding market provides vessels mostly for specialized uses where these vessels are not available in the secondhand market. The prices for these special-purpose vessels are not representative of the price for the typical vessels used to provide marine transportation.

In most situations, the secondhand market will provide a better source of information on the medium-term costs of marine transportation. The exception occurs in periods when trading in the secondhand market is relatively slack even though there is no shortage of capacity.

4. How SHIPCOST estimates vessel costs

The model generates five categories of vessel costs computed for the vessel at sea and in port. The first category is

avoidable costs and includes all variable operating costs less the cost of layup. This cost parameter can be used to estimate charter costs in a market with a reasonable level of excess capacity. Obviously, the actual charter rate could also be used, but those rates would depend on the current market equilibrium whereas the model would compute the rate that would apply if the marginal vessel being employed was the typical vessel. The layup charges are deducted because the vessel owner would incur this cost if the vessel was not being operated.

The second category, operating costs, is similar to the first except that layup costs are not subtracted. This cost parameter is useful when trying to determine the incremental cost for making an additional voyage or adding a leg to an existing voyage. The remaining categories include the operating cost but add a capital charge.

The third category adds the cost of depreciation to the operating costs. The initial purchase price is estimated based on the age of the vessel as well as its size and type, and this price is depreciated using the declining-balance method. The resulting vessel cost can be used to estimate the cost that would appear on a ship operator's accounts.

The fourth category uses the resale value of the vessel as the capital cost. The resale price is adjusted for the age of the vessel as well as the deadweight and type. This price is amortized over the life of the vessel. The resulting vessel costs represents the marginal cost of providing additional capacity to serve an increased level of traffic or the marginal savings which results as a reduction in the level of traffic.

The fifth category uses the newbuilding price for the capital cost. The newbuilding price is amortized over the life of the vessel. The resulting cost can be used to estimate the cost of increasing a dedicated fleet or the cost which will apply in a tight market.

5. Model structure

SHIPCOST has been prepared in four configurations, each one corresponding to a vessel type. The vessel types covered include tankers, dry-bulk carriers, general cargo vessels, and containerships.

The major differences among these configurations are the internal data tables within the model which describe the ship's physical characteristics and capital and operating costs. Within each configuration there are three modules:

- (i) the *fleet module*, which contains the characteristics of the world fleet for that type of vessel;
- (ii) the *ship module*, which determines the costs of operating a vessel of specific size and age; and
- (iii) the *voyage module*, which determines the costs of using a specific vessel on a particular voyage or trade.

The normal sequence is to use the fleet module first to select typical vessel sizes and ages that would be appropriate for the analysis. Next the ship module is used to determine the daily and annual costs of operating these vessels. Finally, the voyage module is used to determine the cost of using these vessels on specific routes carrying selected cargoes. The interaction between modules is shown in Fig. 2.

Fleet module

The fleet module does not perform any analysis. It only accesses tables which describe the size and age distribution of the international oceangoing fleet of vessels. The output is presented in either tabular or graphical form (see Fig. 3).

Ship module

The ship module is the core of the model and can be used to determine the daily costs of a vessel at sea and in port, as well as a number of non-cost characteristics of the vessel.

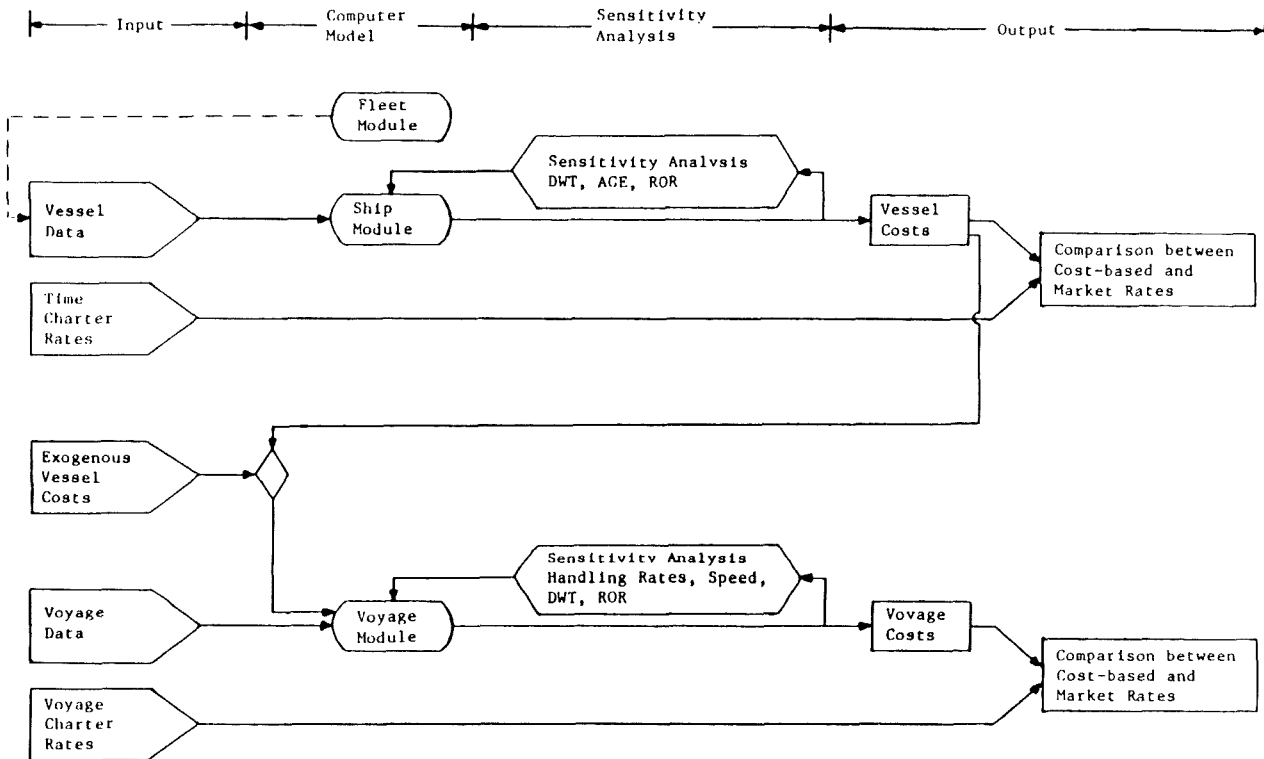


Fig. 2 Interactions between model components

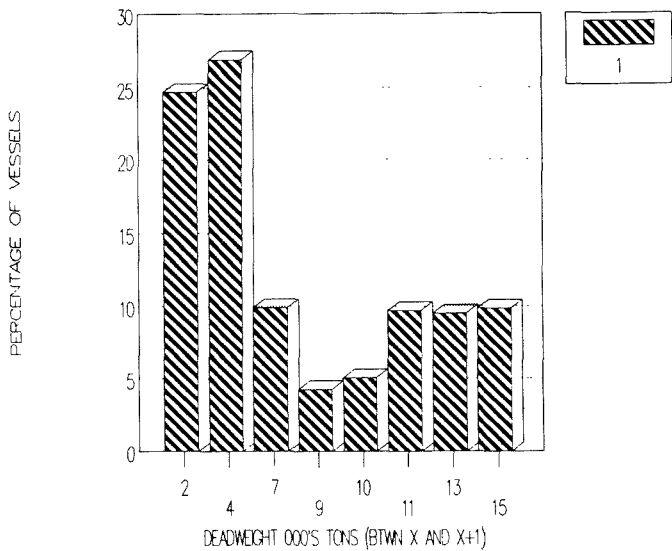


Fig. 3 Sample output of fleet module: distribution by size for general cargo vessels

Figure 4 displays the data input used by the module in screen format. Among these data items, the size of the vessel specified in DWT and the year built are the only essential pieces of information. For containerships the size of the vessel is specified in twenty-foot equivalent units (TEU's). The model then converts TEU's into DWT unless DWT is specified by the user along with the TEU capacity.

The remaining entries are optional in the sense that the model provides default values which can be used whenever the user does not have precise information. The vessel utilization rate is specified as the average number of days per year that the vessel is actually used. The default value is 315 days per year.⁵ The next two entries describe the nationality of the crew. The user has a choice of American, North European, Greek, East Asian or Indian officers and ratings. The Greek crew is the default parameter. The information on crew nationality together with the type of the vessel and its size determines the staffing levels and the wage rates for the officers and ratings. The relationship among crew nationality, crew number and wages was determined from various sources and is contained in a set of internal tables.

Engine type is the next input to be specified. The available options are medium-speed diesel, low-speed diesel, and steam turbine.⁶ Medium-speed diesel engine is the default value. The next entry is the loaded speed of the vessel, which is specified in knots. The default value is the typical design speed for vessels of the specified type and size. If the user specifies a loaded speed higher than the default value, then the vessel will be configured with a larger (than typical) propulsion system and higher fuel consumption. If the speed is lower than the default value, then the propulsion system will be configured for the default value, but the fuel consumption will be calculated assuming slow-steaming at the specified loaded speed.

The entry for type of propulsion is used to compute fuel consumption. The model assumes that medium-speed diesel engines use a mix of 20 percent marine diesel oil (MDO) and 80% high-viscosity oil (HVO), low-speed diesel propulsion systems use a mix of 5 percent marine diesel oil and 95 per-

⁵ It has been assumed that on average 30 days per year are needed for maintenance, and for about 20 days the vessel remains idle.

⁶ Gas turbines were originally included but have since been dropped from consideration.

DAILY COSTS FOR GENERAL CARGO VESSEL, DWT 10,000
1986 VESSEL COSTING MODULE FOR GENERAL CARGO VESSELS,

TYPE OF DATA	VALUE	FORM	UNITS
REQUIRED INPUT DATA			
DEADWEIGHT	10.00	XXX.X	THOUSANDS OF DEADWEIGHT TONNES
YEAR BUILT	1980	19XX	
VESSEL UTILIZATION	315	XXX	DAYS PER YEAR
NATIONALITY OF OFFICERS	3	X	1. U.S.A. 2. EUROPE 3. GREEK
NATIONALITY OF CREW	3	X	4. KOR/SING/PHIL 5. INDIA
ENGINE/FUEL TYPE	1	X	1. MSD 2. LSD 3. STEAM 4. GAS
LOADED SPEED	16.0	XX	KNOTS
FUEL COST	84	XXX.X	\$ PER TONNE
EXPECT. RATE OF RETURN	8	XX.X	% FINANCIAL RATE EXCL. INFLATION
EXPECT. RATE OF RETURN	14	XX.X	% FINANCIAL RATE INCL. INFLATION
CURRENT SCRAP PRICE	115	XXX	\$ PER TONNE
-----ASSUMED VALUES-----			
REPLACEMENT COST OF VESSEL	11.40	XX.XXX	MILLIONS OF \$
REMAINING LIFE OF VESSEL	14	XX	REMAINING YEARS OF USEFUL LIFE
RESALE VALUE OF VESSEL	1.09	XX.XXX	MILLIONS OF \$
ORIGINAL COST OF VESSEL	11.51	XX.XXX	MILLIONS OF \$
NO. OF OFFICERS	12	XX	NO. OF OFFICERS IN SHIP'S CREW
NO. OF RATINGS	21	XX	NO. ABLE-BODIED SEAMEN IN CREW
COST PER OFFICER	17.7	XXXXXX	\$ 000'S/YEAR FOR ONE CREW SLOT
COST PER RATING	10.9	XXXXXX	INCL. BENEFITS, ASUME 2 MEN/SLOT
LENGTH (LOA)	159	XXXX	METERS (IF FEET THEN ft./ 3.28)
BEAM	21	XXX	METERS (IF FEET THEN ft./ 3.28)
SUMMER DRAFT	8.5	XX	METERS (IF FEET THEN ft./ 3.28)
DESIGN SPEED	16.0	XX.X	KNOTS
ACTUAL LOADED SPEED	16.0	XX.X	KNOTS
ACTUAL SPEED IN BALLAST	17.5	XX.X	KNOTS
SHIP (SHIP HORSEPOWER)	6497	XXXXX	S.H.P. FOR MAIN PROPULSION SYST
INSUR. COST (P&I + H&M)	1.2	XX.X	ANNUAL COST AS % OF REPLAC. COST
REPAIR AND MAINTENANCE	1.4	XX.X	ANNUAL COST AS % OF REPLAC. COST
STORES	1.0	XX.X	ANNUAL COST AS % OF REPLAC. COST
PROVISIONS (DAILY)	10.0	XXX	\$ PER CREW MEMBER PER DAY
ADMINISTRATION	10.0	XX.X	ANNUAL COST AS % CREW AND R&M
VESSEL UTILIZATION	315	XXX	AVERAGE NUMBER OF DAYS PER YEAR
VESSEL LIFE	20	XX	NO. OF YEARS OF ECONOMIC LIFE
FUEL CONS-AT SEA LOADED	28.9	XX.X	TONNES FUEL PER DAY (24 HOURS)
- IN PORT	1.8	XX.X	TONNES FUEL PER DAY (24 HOURS)

Fig. 4 Sample input for vessel module

cent high-viscosity oil, and steam turbines use only high-viscosity oil. The model computes the current fuel price per ton based on the above specified mixing ratio. The prices of MDO and HVO can be easily updated; however, if the calculated price per ton of fuel appears unrealistic for the long-run, then the user can enter a different value.

The next two inputs are the expected rate of return with and without inflation. These values refer to the rates of return which are expected in the maritime shipping industry over the long run. They are used to estimate the financial costs to the owners and operators of the vessels. The default value for the expected rate of return in constant terms was assumed to be 8 percent in 1986. The default value for the long-term inflation rate was assumed to be 6 percent, making the default value for the expected rate of return with inflation 14 percent. In the current economic outlook, the inflation rate might be adjusted to 4.5 percent.

The final input for the vessel module is the price of scrap steel. This input is multiplied by the light ship weight of the vessel to determine the vessel's scrap value. Different rates occur depending on the country in which the vessel is being broken and the age and type of the vessel. For the purposes of this model a single rate is sufficient. The model's default rate is the average rate for Far Eastern yards in mid-1986 (\$115/LDT).

The output of the ship module is produced in the format shown in Fig. 5. The daily fuel cost at sea is obtained by multiplying the daily fuel consumption rate by the fuel price

DAILY COSTS FOR GENERAL CARGO VESSEL, DWT 10,000				
OUTPUT VALUES	EXPECTED		HIGH	LOW
FUEL COSTS - IN PORT	0.1	THOUS. OF \$ PER DAY	0.2	0.1
- AT SEA LOADED	2.4	THOUS. OF \$ PER DAY	3.2	1.9
ANNUAL COST OF CREW	441	THOUS. OF \$ PER YEAR	485	397
ANNUAL COST OF PROVISION	104	THOUS. OF \$ PER YEAR	149	66
ANNUAL COST OF INSURANCE	137	THOUS. OF \$ PER YEAR	170	107
ANNUAL COST OF R & M	160	THOUS. OF \$ PER YEAR	210	87
ANNUAL COST OF STORES	114	THOUS. OF \$ PER YEAR	157	87
ANNUAL COST OF ADMIN.	60	THOUS. OF \$ PER YEAR	104	24
ANNUAL NON-CAPITAL COSTS	1016	THOUS. OF \$ PER YEAR (EXCL FUEL)	1277	769
VESSEL CAPITAL COSTS				
IN FINANCIAL TERMS				
IN THOUSANDS OF U.S.	1378	1. FIXED DEPRECIATION-DECLIN BAL	1584	1171
DOLLARS PER YEAR	132	2. ANNUALIZED RESALE VALUE	201	77
BASED ON THE	1161	3. ANNUALIZED REPLACE VALUE	1532	861
METHODS LISTED IN COLUMN G				
LAYUP COSTS	22	THOUSANDS OF \$ PER MONTH	26	17
SCRAPPING PRICE	0.38	MILLIONS OF \$ (LESS 15% DELIVE	0.42	0.34
RETURN ON SALVAGE	30	THOUSANDS OF \$ PER YEAR	59	48

SENSITIVITY TEST FOR GENERAL CARGO VESSEL, DWT 10,000

VESSEL COST SUMMARY TABLE (THOUSANDS OF US\$ PER DAY AT SEA)				
---AT SEA---	---IN PORT---	---METHOD---		
2.8	0.5	1.	AVOIDABLE COSTS - LAYUP (EXCLUDES CREW)	
5.7	3.4	2.	OPERATING COSTS	
19.0	7.7	3.	FIX DEPREC. (DECLIN BAL.) + OPER. COSTS	
6.1	3.8	4.	ANNUALIZED RESALE VALUE + OPER. COSTS	
9.3	7.1	5.	ANNUALIZED REPLACE VALUE + OPER. COSTS	

Fig. 5 Sample output from ship module

described above. The fuel consumption rate is calculated based on the vessel's DWT and actual loaded speed. The formula used for this calculation is:

$$r = \frac{V^3 (DWT)^a}{b * f(V/V_0)} \cdot c$$

where

- r = daily fuel consumption rate
- V_0 = design speed
- V = actual loaded speed
- $f(x)$ = thermal efficiency ratio, as a function of the V/V_0 ratio
- a, b = regression coefficients relating speed and vessel size to fuel consumption
- c = standard unit consumption factor relating type of engine and fuel consumption.

The daily fuel consumption rate in port is obtained as a function of the vessel's type and size, based on information collected from various sources and stored in the model's data tables.

The annual costs of insurance (including P&I and H&M insurance, but not cargo insurance), repair and maintenance (R&M), and stores (excluding provisions) are calculated as a percentage of the vessel type and its replacement cost. The cost of provisions depends on the crew size and its nationality.

Administrative costs can represent a major cost of providing maritime transportation. The administrative responsibilities for a single vessel or a fleet include recruiting and training crews, ordering supplies and spare parts, arranging for

maintenance and repairs, obtaining insurance, marketing vessel services, planning vessel routes and personnel travel, billing for services, maintaining accurate accounts, and managing the communications between the vessel and staff.

The costs for administration are difficult to estimate since they depend on a variety of factors, including the size of the fleet being managed, the extent to which ships' agents are used, and the size of the overseas offices and staff. The three primary factors are the type of trade (liner services have much higher administrative costs than charter services primarily due to marketing requirements), the country in which the administration is conducted, and the extent to which the management of the vessel is contracted out.

In addition, the administrative costs will increase will increase with vessel size to the extent that:

- (i) more supplies, fuel, and stores must be ordered and accounted for;
- (ii) more manpower is required during drydockings, surveys, and repairs; and
- (iii) the area over which the vessel operates is larger.

For the purposes of the model, it was assumed that administrative costs are proportional to the annual costs of crew and repairs and maintenance. This percentage can be adjusted based on the type of trade.

The replacement cost (newbuilding price) of the vessel was estimated from the reported sales data using the following general relationship:

$$\text{Price per DWT} = a \cdot (DWT)^b$$

Resale prices are derived by discounting the newbuilding prices for the vessel. The discounting is done using a fixed percentage per year. This factor was derived by regression analysis of the purchase and sales data published in the maritime literature.

In addition to the cost figures shown in Fig. 5, the model output includes the physical dimensions of the vessel, the number of officers and ratings in the crew, and the size of the main propulsion unit. Among these non-cost parameters, only the size of the crew is used directly in estimating costs. The effects of the variation in the other physical parameters is accounted for by estimating high and low values for capital and operating costs (refer to Fig. 5).

The size of the main propulsion unit is given by the formula

$$\text{BHP} = a \cdot (DWT)^{2/3} \cdot V^3 + b$$

where a and b are regression coefficients estimated from a large sample of data obtained from vessel statistical data.

The most important feature of the SHIPCOST model is the variety of capital and operating costs computed. The model calculates these costs for typical vessels, but it can provide a more precise estimate of a vessel's operating cost if the user provides additional data for a specific vessel. The second most important feature is the ability to perform sensitivity analysis. This analysis determined the change in the capital and operating cost of a vessel as a function of its size, age and speed. Sample results of these tests are presented in either graphical or tabular form as shown in Fig. 6.

Voyage module

The voyage module computes the costs for operating a specific vessel over a designated route carrying a single type or form of cargo on each leg of the voyage. Data on the daily costs of the vessel can be entered by the user or can be obtained from the ship module. The user specifies the route as a two- or three-legged voyage. The voyage is defined by the type of cargo on each leg, the handling rates at the origin and destination of each leg, the fixed delays for each cargo transfer operation, and the tariff rates for each cargo han-

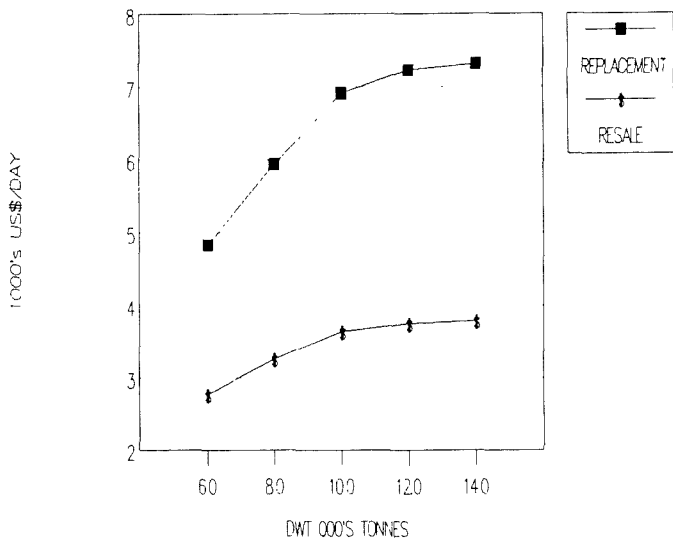


Fig. 6 Output of vessel module sensitivity tests: DWT versus operating + capital costs for general cargo vessels, Greek crews

ding operation. The screen format for the input is shown in Fig. 7.

The voyage module computes not only the vessel capital and operating costs, but also the financial costs of the cargo in transit and, if wanted, the port charges. The cargo-related costs are determined by specifying the type and value of the cargoes being transported. The port charges are determined by entering a simplified version of the port tariff to account for vessel and cargo-related charges.

The vessel costs at sea are determined by first specifying

TEST OF THREE LEGGED VOYAGE
1986 VOYAGE COSTING MODEL

VESSEL DATA

SIZE	35750	XXXXX DEADWEIGHT; XXXX TEU
UTILIZATION	315	DAYS PER YEAR; R&M DAYS/YR
LOADED SPEED	18	KNOTS; IDLE DAYS/YEAR
VESSEL CAPITAL COST	9.43	US\$ 000'S/DAY;BALLAST SPEED
-CREW COST	2.67	US\$ 000'S PER DAY
-OTHER COST	4.30	US\$ 000'S PER DAY
-FUEL COST AT SEA	6.87	US\$ 000'S PER DAY
-FUEL COST IN PORT	0.21	US\$ 000'S PER DAY

VOYAGE LEG

	1	2	3
ORIGIN PORT	23	23	23
DESTINATION PORT	23	23	23
DISTANCE	410	628	5000

1. E. coast USA 2. W. coast USA 3. Caribbean/Gulf coast USA
 5. W. coast Central America 6. S.W. South America 7. W. co
 8. N.E. South America 9. U.K./N.W. Europe 10. Persian Gulf 1
 12. E. Mediterr. 13. N.E. Africa 14. W. Africa 15. S.W.
 16. S.E. Africa 17. S. Africa 18. South Asia (India) 19.
 20. E. Asia (Japan/Korea) 21. E. Australia 22. W. Austral

CARGO COMMODITY

	LEG 1	LEG 2	LEG 3
MAXIMUM CAPACITY	2250	2250	2250
VALUE OF CARGO	2635	2635	2635

1. crude 2. oil products 3. grain 4. iron ore 5. coal 6. ba
 7. alumina 8. other mineral 9. other dry bulk 10. other li
 11. breakbulk 12. containerized cargo 13. empty leg - in ba

	PORT 1->2	PORT 2->3(1)	PORT 3->1
AMOUNT LOADED	1000	500	750
AMOUNT UNLOADED	400	750	1100
NET LOADING RATE	1200	1200	1200
NET UNLOADING RATE	1200	1200	1200
FIXED ACCESS TIME			
-LOADING FACILITY	1.5	1.5	1.5
-UNLOADING FACILIT	1.5	1.5	1.5

Fig. 7 Input format for voyage module

which of the five categories of the vessel costs is to be used. The selected cost is then computed for the designated type, size, and operating speed. This cost is then multiplied by the transit time for each leg of the voyage.

The vessel costs in port are determined from the time spent in port, which includes the access/egress time and the time spent loading and unloading the cargo. The port charges are determined from the simplified port tariff, the amount of cargo transferred and the time the vessel spends in port.

The cargo inventory costs are determined from the daily interest charges on the cargo carried on each leg. This figure is multiplied by the time spent transiting the leg and the time spent in the origin port loading the cargo and in the destination port unloading the cargo.

A sample of the voyage module input and output are shown in Fig. 8 for a typical triangular voyage. The costs incurred while in transit are identified separately from those incurred while in port. The total voyage costs are computed by summing the costs on each leg of the route. Once the voyage costs have been determined, the annual cost of a vessel dedicated to this route can be estimated by calculating the number of voyages that could be completed in a year. Since different cargoes would be carried on the individual legs and different load factors would apply, it does not make sense to determine an overall cost per ton carried. Therefore the model computes are per-ton transport costs for each leg of the voyage.

The voyage module can be used as a stand-alone model without the vessel module. In this configuration, the user specifies the daily cost parameters shown at the top of Figure 8 for a specific vessel.

The type of transportation service represented in the voyage module can be a single voyage, multiple voyages or an annual service. This module also performs sensitivity tests on voyage cost relative to cargo handling rates. When combined with the ship module, the voyage module can also perform sensitivity analysis with respect to vessel size and speed.

TEST OF THREE LEGGED VOYAGE

VOYAGE DESCRIPTION - FROM	TO	New York	Baltimore	Savannah
FINANCIAL COSTS				
TRAVEL TIME	LEG 1	LEG 2	LEG 3	
PORT TIME	0.95	1.45	11.57	
-LOADING FACILITY	0.90	0.48	0.69	
-UNLOADING FACILITY	0.40	0.69	0.98	
VESSEL COST				
-IN TRANSIT	22.08	33.81	269.22	
-LOADING FACILITY	14.88	7.96	11.42	
-UNLOADING FACILITY	6.57	11.42	16.26	
TOTAL VESSEL COSTS	43.53	53.19	296.90	
PORT CHARGES				
-AT LOADING PORT	0.00	0.00	0.00	
-AT UNLOADING PORT	0.00	0.00	0.00	
TOTAL PORT CHARGES	0.00	0.00	0.00	
CARG. INVENTORY COST	2.26	2.65	13.38	
DURING VOYAGE WITH	14.00%	RATE OF INTEREST		

-----TOTAL FINANCIAL VOYAGE COSTS-----

TOTAL VESSEL COST	393.61	\$000's/VOYAGE
TOTAL PORT CHARGES	0.00	\$000's/VOYAGE
TOTAL VOYAGE COST	393.61	\$000's/VOYAGE
TOTAL VOYAGE TIME	18.10	DAYS/VOYAGE
VOYAGES PER YEAR	17.0	
TONS LOADED PER YR.		
-LEG1	17000	TEU
-LEG2	8500	TEU
-LEG3	12750	TEU
TOTAL COST PER YEAR	6.81	MILLIONS OF \$
(LESS CARGO INVENT)		
TOT. COST/TOT. LOADED	\$178	\$ PER TEU
(LESS CARGO INVENT)		

Fig. 8 Sample output for voyage costs

6. Model applications

The model has been used for a wide variety of projects involving transportation projects as well as analyses of transport costs. The basic application has been in port development projects where the model is used to estimate the cost of vessel time in port. This cost is then used to compute the value of the savings in port time which will result from the investment of new berths, better cargo handling equipment or other infrastructure which reduces the time a vessel spends in port.

Prior to the introduction of this model, the vessel costs were determined from a small sample of vessel costs which were generated from ship management records. These estimates used newbuilding costs to estimate the capital costs. Now resale value is being used to determine the capital cost. This change is important because the investment in port facilities or other transport infrastructure must consider the market which is being served. In periods of excess capacity when vessels are slow steaming to reduce fuel costs, it is unlikely that a reduction in port turnaround time will be translated into additional employment for the vessels calling at the port. If anything it will add to the excess capacity and in this way may reduce shipping rates. In periods of peak demand, congestion charges are introduced as a measure of the cost of delay to a vessel, but a more accurate measure can be obtained using the SHIPCOST model.

The SHIPCOST model has also been used to look at dedicated services primarily for bulk and neo-bulk cargoes. In these situations, the model provides a quick estimate of the marine transport costs which can then be used to determine the economic viability of transporting the cargo. The model can also be used to determine the combination of vessel size, operating speed and port cargo-handling rates which will result in the lowest transport cost.

The model's capacity for computing voyage costs using different definitions of vessel costs has been very useful when analyzing shipping tariffs. The operating costs by themselves provide the minimum rate appropriate for backhaul cargo.⁷ The operating cost plus depreciation represents the conference rate for median-value cargo assuming that the calculation is made for the crew and vessels of the high-cost operator in the conference. High-value cargo will be charged at a higher rate. If the rates rise above the newbuilding cost plus operating costs, then it is likely that there will be new entrants and rates will be forced down.

The SHIPCOST model is also useful for evaluation port tariffs. The development of effective port tariffs requires a knowledge not only of the costs of port operations but also of the vessel operators serving the port. The simplified port tariff included in the voyage model allows for an estimate to be made of the magnitude of port charges relative to the rest of the voyage costs. Alternatively, a more detailed analysis of port charges can be prepared by port management and combined with the voyage cost estimates provided by the SHIPCOST model. This analysis can be particularly useful when a port is introducing a new service or improving an existing service and wants to estimate the value of the resulting savings to the vessel operators in port and voyage time.

A final use of the SHIPCOST model is the calculation of the additional vessel costs incurred in making a port call. The model is used first to compute the voyage costs for the existing route and then to compute the voyage costs with the new port added to the route. The decision of a vessel owner to make an additional port call depends on the difference between the additional cost of diverting the vessel to the port and the

increase in revenues resulting from the additional volume of cargo which would be obtained by calling at the port.

This analysis becomes more complex where there is an option for transporting the cargo, albeit at higher cost, through a port which is already on the route. Assuming that no additional cargo would be generated by calling at the port, the tradeoff is between the savings in land transport costs by handling the cargo through the new port and the additional cost of calling at this port. The SHIPCOST model is used to estimate the diversion cost. If the current fleet is underutilized, then only the operating costs for the vessel would be used. If the fleet is utilized to the point where the additional time spent calling at the port would have to be made up by chartering additional capacity, then the resale value can be used for the capital charge.

As an example of the diversion problem, we would like to consider the cost of adding Baltimore to a container service to North Europe which presently calls at Elizabethport and Savannah. The cost of diverting to Baltimore includes the cost of moving up and down the Chesapeake at 17 knots and the costs of access and egress to the port of Baltimore. It is assumed that the total time spent transferring boxes would not be significantly different. For a typical 2500-TEU vessel with North Europe crew and officers, the round-trip voyage costs would be as shown in Table 1. The access and egress time at Baltimore, which includes berthing, unberthing and preparing the ship before and after cargo handling operations, is assumed to be three hours.

Other costs are incurred due to the delays associated with waiting for the start of a shift. Also, there are the charges for stevedoring as well as port services. We have not included these items because they require a more precise knowledge of the vessel schedule and the relative charges at the three ports. The results in Table 1 indicate that for a fleet with excess capacity the cost of the diversion per voyage would be only about \$15 000. Assuming that 500 TEU were transferred on each call, then the port call would appear to be justified if the additional cost to transport these boxes to either Savannah or Elizabethport is greater than \$30. However, this cost does not include the additional administrative costs of providing shipping and receiving services in Baltimore. Also, even if the differential land transport cost is higher than \$30 per TEU, the ship operator still might not call at Baltimore if the resulting increase in total voyage time introduced costs which were greater than the potential savings in land transport costs.

Table 1 Marginal costs of vessel call at Baltimore

ASSUMPTIONS
• 2500-TEU container vessel
• Built in 1982, valued at resale value
• 18-knot loaded speed
• North European Crew and Officers
• Handling Rates are the Same in All Ports
• European Leg Simulated by 5000 mile loop
• Port Charges Not Included
NEW YORK-SAVANNAH-EUROPE
Trip Time-17.4 days
Trip Cost-\$378.7 thousand
NEW YORK-BALTIMORE-SAVANNAH-EUROPE
Trip time-18.1 days
Trip cost-\$393.6 thousand
Marginal Cost for 500 TEU-\$30/TEU
Marginal cost if full day added to voyage-\$41/TEU

⁷ A more appropriate measure would be the marginal cost of carrying additional cargo, but the model is not set up to estimate this cost.

7. General specifications

SHIPCOST is designed to operate on an IBM PC or compatible micro-computer. It is written in LOTUS 1-2-3 (release 2.0), but knowledge of the software package is not required since the model is menu-driven. Data entry is under the control of the program. It requires one disk drive and at least 384K of RAM memory. The computation time for each module is five seconds or less.

The model is designed for periodic updating. For the most frequent updates, such as the price of fuel and scrap steel, the user can either change the values each time the model is used or change the default values and store them with the program. For those parameters which change yearly such as crew wages, newbuilding costs, resale factors, and inflation

indexes, an annual update is performed by modifying the data tables in the model. For long-term changes, such as reductions in fuel consumption and manning requirements, changes in average operating speeds, and adjustments in fleet and vessel characteristics, an update is prepared every two to four years. This update involves a review of the literature and statistical analysis of the data. The results of this analysis are used to revise the constants in the program's formulas as well as the values in the data tables.

References

- 1 Zannetos, Z., *The Theory of Oil Tankship Rates. An Economic Analysis of Tankship Operations*, The MIT Press, Cambridge, Mass., 1966.
- 2 Jansson, J. O. and Shneerson, D., *Liner Shipping Economics*, Chapman and Hall, New York, 1987.