THE TURNROUND OF CARGO LINERS AND ITS EFFECT UPON SEA TRANSPORT COSTS*

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INTRODUCTION

It is often suggested that cargo liners spend an excessive amount of time in port and that, if this could be reduced, substantial reductions could be achieved in the cost of sea transport. The object of this paper is to test this hypothesis and to present calculations indicating the orders of magnitude involved in various combinations of route length and turnround time. Although the data and assumptions do not refer to any specific route, cargo or shipowner, they are believed to be not unreasonable for present circumstances and applicable to most competitive shipowning countries.

BASIC DATA[1]

In order to isolate the effects of the variables being considered one ship design is assumed throughout. This is a typical modern cargo liner of:

(a) 10,000 grt. (closed shelter deck).
(b) 12,500 dwt. tons.
(c) 16 knots with single-screw, super-charged diesel engine of 9,200 S.H.P., having an exhaust boiler for some auxiliary services and diesel generators for use in port and providing an overall specific fuel consumption of 0.36 lbs per S.H.P./hour at sea and 2 tons per day in port, both at an average of 100s. per ton of oil. This gives a fuel cost of £177 per day at sea and £10 per day in port.
(d) 650,000 cu. ft. bale capacity.
(e) 42 crew.

Assuming that the ship is, on average, 80% full and makes three round voyages a year when spending 60% of its time in port, the costs according to the usual headings are as follows:

*I am indebted to colleagues in H.M. Treasury, the Board of Trade, the National Ports Council and the British Transport Docks Board for commenting on earlier drafts of this paper and to H.M. Treasury and the Board of Trade for permission to publish it. I alone am responsible for the views expressed and for any errors and omissions.

[1]These data were published in an earlier paper: "Investment in Shipping and the Balance of Payments", *Journal of Industrial Economics*, March 1965.

Table I. The costs of a cargo liner

	£ *per day*	£000 *p.a.*
Commissions	—	27
Cargo-handling	—	136
Fuel	—	28
Port dues, pilotage, tug hire, Customs fees, etc.	—	50
Crew wages	150	55
Crew provisions	21	8
Stores, including lubricating oil	30	11
Repairs	125	46
Insurance	55	20
Sundries	11	4
Administration	55	20
TOTAL	£447	£405

The capital cost is £1,250,000. This is equivalent to capital charges on the basis used in this paper (see below) of £298 per day or £108,981 p.a. at a discount rate of 6%. The conventional accounting procedure of straight-line depreciation plus 6% interest on the mean of book values in the first and last years would give capital charges of £278 per day.[2]

ASSUMPTIONS

(a) *Cargoes:* All cargoes occupy 80% of the bale capacity at an average density (including broken stowage) of 65 cu. ft. per long ton. Each cargo is, therefore, of 8,000 long tons. If the broken stowage were 10% there would be about 11,800 measurement tons of 40 cu. ft. in the cargo and a stowage factor, excluding broken stowage, of 59 cu. ft. per long ton.

(b) *Voyages:* All voyages involve two such cargoes, loading and/or discharging being carried out at two ports at each end of each passage. There are, therefore, four port calls in each (round) voyage.

[2]On the basis (5% depreciation + 7% on the full replacement cost of the ship) used by P. A. Lane in "An Aspect of the Cost of Port Delays", *Yorkshire Bulletin of Economic and Social Research*, Nov. 1957, the capital charges would have been £150,000 p.a. or £411 per day. The daily cash costs in port in this paper are £447 + £212 (port charges – see below) + £10 (fuel) = £669. Martin-Jenkins and Sir Nicholas Cayzer (*op. cit.*, below), in implying or quoting daily costs of £545 and £600 respectively, would appear to have excluded capital charges altogether. The O.E.C.D. publication *Maritime Transport* 1963 at p. 37 suggests £670 per day for "operating costs, depreciation and normal interest on capital" (on an unspecified basis and rate) but excludes the additional port dues included here. The figures used in this paper are thus some 12½% greater than those assumed by O.E.C.D.; this may be due to differences in the method of calculating capital charges or in the ship taken as an example.

(c) *Commissions and cargo-handling costs:* These costs do not normally vary with route length, and, while cargo-handling costs might vary inversely with turnround times (e.g. if shift premia or different techniques were employed), they are assumed constant here in order to isolate the effects of varying one voyage component at a time. Since the data in Table I refer to 6 cargoes of 8,000 long tons each, it follows that commissions cost £0·565 and cargo-handling £2·833 per long ton.

(d) *Port charges:* Exit and entry costs (*e.g.* tug hire, pilotage and linesmen) are assumed to cost £300 per port call. With 12 port calls per year this leaves £46,400 p.a. to be accounted for by other port charges, *e.g.* tonnage dues payable by the ship. If all of this represents tonnage dues it is equivalent to 5·088d. per g.r.t./day or £212 per day in port. This last figure is equivalent to a daily berth-rent. It may appear high in relation to some current price levels, but it must be remembered that these reflect only the general practice among port authorities of attempting to raise sufficient revenue to defray their cash costs (including explicit interest charges) plus depreciation, and that depreciation is only sometimes on a replacement cost basis.

(e) *Repair costs and periods:* Ships are subject to quinquennial surveys by classification societies, and these are of increasing severity. A given ship's time-stream of net cash flows thus tends to be extremely uneven, partly because of the increased repair costs and partly because of the (necessarily simultaneous) fall in revenue. (The earlier surveys can be carried out without interrupting the ship's trading and thus without reducing revenue: the later ones cannot.) Given the type of ship and assuming the latest technical standards, it is reasonable to assume that repair costs are not significantly affected by changes in route length or turnround times. User cost is ignored here, partly because reliable evidence is not available and partly because it appears to have both positive and negative elements. The positive element is the increased wear and tear on cargo-handling gear (principally derrick runners and blocks), the increased damage to the ship's holds and hatchways and the increased engine-hours per year associated with greater annual carryings. The negative element is the reduced underwater fouling which results from shorter stays in port. This treatment is only one of a number of points on which the approach adopted here differs from that of P. A. Lane.[3] For comparative purposes, therefore, the level of repair costs and of repair periods may be assumed to be constant over the ship's life. This will, however, slightly reduce the validity of the absolute levels of cost shown later.

(*f*) *Life of the ship:* This is assumed to be 20 years. The results of this paper would not be significantly affected if a life of 25 years were assumed.

(g) *Opportunity cost of capital:* This, the rate of return that might reasonably be expected in the next best alternative investment, is crucial to such calculations; without it the rate of return above which investors may reasonably be expected to order ships, and below which they may reasonably be expected to cease ordering them, cannot be defined. An assumption on this cannot be avoided, and must refer to a rate net of taxes, etc., and in real terms. Partly because there is some doubt as to the

[3]P. A. Lane, *op. cit.*, assumed one-third of repair costs varied with the level of activity but did not mention the negative element of user cost. His paper was an analysis of historical variations in turnround of cargo liners in the U.K./Australia trade.

opportunity cost of capital, and partly to test the sensitivity of such calculations as these to small variations in it, two rates will be assumed here: 6% and 8%. As this concept refers to the returns likely to be made on other investments than shipping, neither of these figures has any necessary relation to the rates of return, internal or on capital employed, obtained in shipping over any particular period.

(h) *Demand:* It is assumed that cargoes will continue to be available at the same freight rates even though the effective annual carrying capacity of the ship is increased. The validity of this assumption will be discussed on page 88.

PRELIMINARY CALCULATIONS

(a) *Cargo* per round voyage = 16,000 long tons

(b) *Cost per cargo* per round voyage

Commissions 16,000 tons at £0·563	= £ 9,008	
Stevedoring 16,000 tons at £2·833	= £45,328	
Exit and Entry charges: 4 calls at £ 300	= £ 1,200	
Total cash cost for cargo per round voyage		= £55,536

(c) *Cost per day at sea*

Cash operating costs	at £447	
Bunkers	at £177	
Total cash cost per day at sea		= £ 624

(d) *Cost per day in port*

Cash operating costs	at £447	
Bunkers	at £ 10	
Port charges	at £212	
Total cash cost per day in port		= £ 669

METHODS[4]

A shipowner will tend to build ships if and when he thinks that it will be profitable for him to do so; and this depends, among other things, on the level of freight rates.

[4]The methods adopted here contrast with those of R. L. Marris in his recent book: *The Economics of Capital Utilisation* (Cambridge, 1964) in three principal ways. First, Marris uses private profit rather than the concept of social cost as measured by shadow price; but if every firm adopts new, profitable techniques (and there seems no very good reason why it should not) then prices and profits will be competed down to a "normal" level. The reduction in social costs will remain: nor is it represented by the difference in the profit rate caused by prices being competed downwards. Secondly, Marris seems content with using crude rates of return to indicate the optimal choice amongst alternative proposals. Thirdly, this paper is not concerned solely with *capital* utilisation: when a ship is used more intensively in port there are associated reductions in the average costs (per ton of cargo delivered) of the crew, fuel, repairs, stores, insurance and administration.

The profitability of a proposed ship may be expressed in terms of its net present value, or the excess of the discounted net cash flows over the capital cost of the ship.[5] This may be expressed mathematically as

$$NPV = \sum_{i=1}^{i=n} \left[A_i \, (1 + r)^{-i} \right] - C_o$$

where i is a year of the ship's life
n is the total life of the ship
A is the net cash flow (*i.e.* the excess of cash revenue over cash costs)
r is the opportunity cost of capital and
C_o is the initial cost of the ship.

The cash flow may be taken either before or after taxes, etc. At the margin of profitability, *i.e.* where NPV=zero, the present value of corporation tax and tax allowances taken together is, for British shipping, approximately zero.[6] Because the subsequent calculations will all be made on the basis of such an internal rate of return, taxes and tax allowances may be ignored. As far as the calculations in this paper are concerned, investment grants are also ignored, but this makes little difference to the results – certainly less than the difference between using discount rates of 6% and 8%. Alternatively, the calculations may be regarded as being in social rather than private terms.

Because we are assuming that repair costs and periods are constant over the ship's life, and because there seems no obvious reason to suppose that any other cost items will vary sufficiently, or with sufficient predictability, to affect the conclusions, we may assume that the net cash flow time stream is flat. This enables us to simplify our formula to:

$$NPV = A \left[\frac{1 - (1 + r)^{-n}}{r} \right] - C_o$$

Values of $\left[\frac{1 - (1 + r)^{-n}}{r} \right]$ may, of course, be obtained from annuity tables.

Where r = 6% and n = 20 years, the value is 11·4699, and where
r = 8% and n = 20 years, it is 9·81815.

The net cash flow expression A may, of course, be expanded into (R_c—C_c), where R_c is the gross (cash) revenue and C_c the cash costs for a year. The assumptions given above are sufficient to calculate C_c for any desired combination of circumstances. The revenue expression R_c may in turn be expanded into (P x Q) where Q represents the tonnage of cargo carried in a year (for which the above assumptions are also sufficient) and P represents the freight rate.

It is, therefore, possible to rewrite the equation as:

[5]For a further discussion of this subject in a shipping context see R. O. Goss: "Economic Criteria for Optimal Ship Design", *Trans. Royal Inst. Naval Architects*, Oct. 1965. In a general context the subject has been covered in a number of recent works.

[6]*Cf.* R. O. Goss: "The Economics of Automation in British Shipping", *Trans. Royal Inst. Naval Architects* (forthcoming).

$$NPV = (PQ - C_c)\left[\frac{1 - (1 + r)^{-n}}{r}\right] - C_o$$

and to solve it for the freight rate which is equivalent to the assumed internal rate of return by assuming NPV = zero and transposing it into:

$$P = \frac{1}{Q}\left(\frac{C_o}{\left[\frac{1 - (1 + r)^{-n}}{r}\right]} + C_c\right)$$

for which values may easily be calculated.

The values of P thus produced may be termed the "shadow price" of using the given ship in the given circumstances. This measure takes into account the operating costs concerned, the capital cost of the ship (thus any inclusion of depreciation would involve double-counting), the rate of return expected in the long run and the quantities of cargo concerned. It may be noted that, if sufficient data on repair costs and periods were available, it would be possible to relax the assumption of Q and C_c being constant by solving the formula:

$$C_o = \sum_{i=1}^{i=n} (PQ_i - C_{ci})\ (1 + r)^{-i}$$

for P by trial and error.

It is, in other words, possible to calculate a shadow price which takes account, not only of those costs mentioned in the preceding paragraph and assumed in this paper to be constant over the ship's life, but also of any specified variations in these costs over the life of the ship. Moreover, it is also possible to consider the effects of any specified variations in the level of output over the life of the ship. As noted above, however, this is likely to affect the absolute levels of the shadow prices rather than comparisons made between them for the purposes of this paper.

To recapitulate the argument thus far: Whether or not the time stream of net cash flows is flat, it is reasonable to assume that, at any freight rate above the shadow price as defined above, the higher rate of return obtainable by investment in ships will bring forth an increased supply of ships, whereupon competition will bring the rate down again. Conversely, at any rate below P, shipowners will be less willing to order ships, the supply of ships will be reduced and the rate will rise again. P is therefore the long-term equilibrium rate about which market rates will tend to fluctuate and towards which, with given techniques, they will have a long-term tendency to move. Given the competitive nature of the shipping industry and the ability of outsiders to compete their way into shipping conferences, such differences are also likely to indicate differences in the general level of freight rates. The length of the time lags involved in correcting imbalances in world supply and demand for ships (the slump which started in 1957, for example, did not begin to end till 1963) might, however, delay the appearance of such effects. It should not be inferred from these calculations that there is anything "just" about these levels of freight rate, or that there is anything "unjust" about any other level. Market rates must always reflect the world supply-demand position of shipping (and also the distortions caused by national policies of, *e.g.*, flag discrimination and subsidies)

RESULTS

Calculations have been made on:

(a) Round voyage distances of 5,000, 10,000, 15,000 and 20,000 nautical miles, and

(b) turnround times involving 0, 10, 20, 30, 40, 50 60,, 70 and 80% of the year being spent in port.

The shadow prices thus obtained are shown in Table II.

Table II. Variations in the shadow prices of cargo-liner services with route length and turnround times

% *of year spent*		*Round voyage distance, n.m.*							
in port	*at sea*	5,000		10,000		15,000		20,000	
		6%	8%	6%	8%	6%	8%	6%	8%
		£	£	£	£	£	£	£	£
80	20	7·37	7·57	11·26	11·67	15·15	15·77	19·05	19·86
70	30	6·05	6·19	8·64	8·91	11·22	11·63	13·79	14·33
60	40	5·40	5·50	7·33	7·53	9·26	9·56	11·18	11·59
50	50	5·01	5·09	6·54	6·71	8·08	8·32	9·61	9·94
40	60	4·75	4·81	6·02	6·15	7·29	7·50	8·57	8·84
30	70	4·56	4·62	5·64	5·75	6·73	6·90	7·82	8·05
20	80	4·42	4·47	5·36	5·47	6·31	6·47	7·26	7·46
10	90	4·31	4·35	5·15	5·24	5·98	6·12	6·82	7·00
0	100	4·22	4·26	4·97	5·05	5·72	5·84	6·47	6·63

Some of the principal results of this calculation are already clear:

(a) the shadow price is not very sensitive to changes in the opportunity cost of capital;

(b) the shadow price is sensitive to changes in the proportion of time spent in port, particularly on the longer routes;

(c) the shadow price appears to be very sensitive to changes in the round voyage distance, particularly when the proportion of time spent in port is high. This, however, is not a fair test, since, with a constant *proportion* (rather than a constant absolute amount of time) in port, increasing distance is associated, in Tables II and III, with increasing periods not only at sea but also in port. Accordingly, comparisons should be made between the lines of these tables rather than between the columns.

More detailed results of the same calculations, showing round voyages p.a., port, sea and total days per round voyage, output (*i.e.* tons carried p.a.) and cost per ton-mile, are shown in Table III. The implied rates of cargo handling, in tons per gross port day (*i.e.* including weekends and public holidays) are shown in Table IV.

The most important results of these calculations lie not so much in the absolute as in the proportionate changes of the shadow prices. These changes can be observed

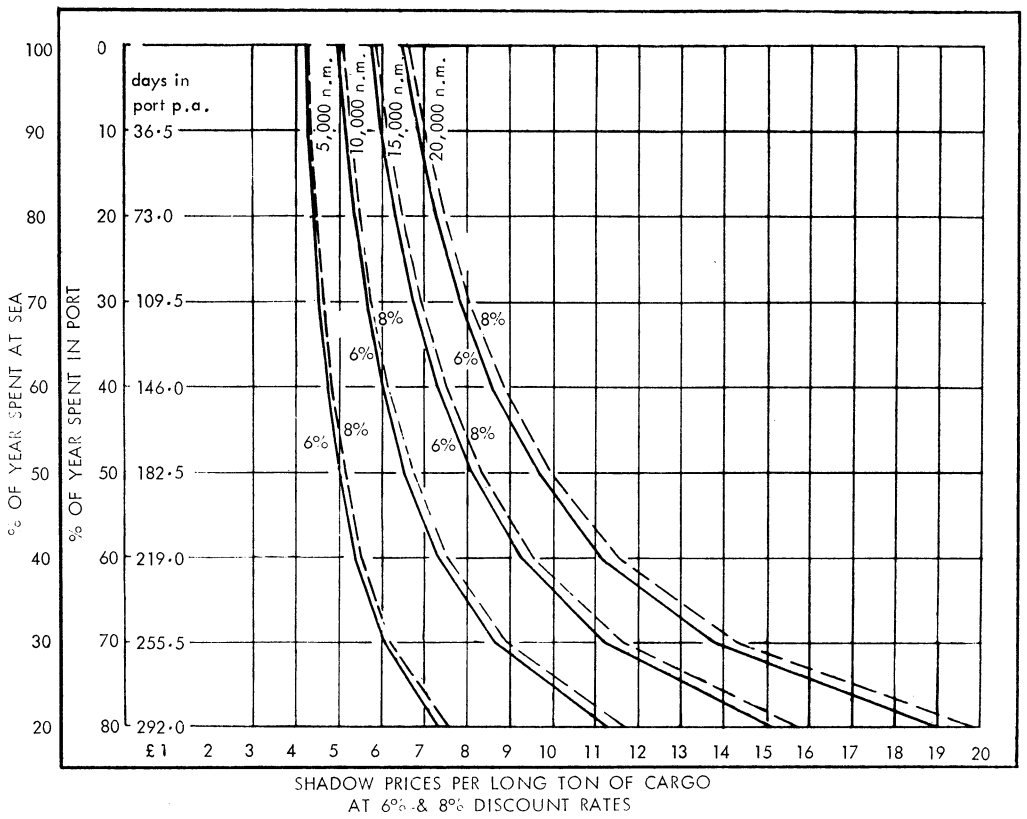
Table III. Round voyages p.a., port, sea and total days p.r.v., annual carryings and cost per ton-mile for various combinations of turnround and r.v. distance

	% of year		Round voyage distance n.m.			
	in port	at sea	5,000	10,000	15,000	20,000
Round voyages p.a.			8·4	4·2	2·8	2·1
Port days p.r.v.			30	61	91	121
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	70	30	43	87	130	173
Tons carried p.a.			134875	67357	44924	33759
Cost per ton-mile £			0·00242	0·00173	0·00150	0·00138
Round voyages p.a.			11·2	5·6	3·7	2·8
Port days p.r.v.			19½	39	58½	78
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	60	40	32½	65	97½	130
Tons carried p.a.			179690	89826	59896	44931
Cost per ton-mile £			0·00216	0·00147	0·00123	0·00112
Round voyages p.a.			14	7	4·7	3·5
Port days p.r.v.			13	26	39	52
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	50	50	26	52	78	104
Tons carried p.a.			224614	112307	74872	56155
Cost per ton-mile £			0·00200	0·00131	0·00108	0·00096
Round voyages p.a.			16·8	8·4	5·6	4·2
Port days p.r.v.			9	17	26	35
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	40	60	22	43	65	87
Tons carried p.a.			269125	134875	89845	67357
Cost per ton-mile £			0·00190	0·00120	0·00097	0·00086
Round voyages p.a.			19·6	9·9	6·6	4·9
Port days p.r.v.			6	11	17	22
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	30	70	19	37	56	74
Tons carried p.a.			313980	157837	104846	78599
Cost per ton-mile £			0·00182	0·00113	0·00090	0·00078
Round voyages p.a.			22·4	11·2	7·5	5·6
Port days p.r.v.			3	6½	10	13
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	20	80	16	32½	49	65
Tons carried p.a.			358284	179693	119673	89845
Cost per ton-mile £			0·00177	0·00107	0·00084	0·00073
Round voyages p.a.			25·3	12·6	8·4	6·3
Port days p.r.v.			1½	3	4	6
Sea days p.r.v.			13	26	39	52
Total days p.r.v.	10	90	14½	29	43	58
Tons carried p.a.			405555	202075	134875	101039
Cost per ton-mile £			0·00172	0·00103	0·00080	0·00068

Table IV. Tonnage of cargo handled per gross port-day

% of Year		Round Voyage Distance n.m.			
in port	*at sea*	5,000	10,000	15,000	20,000
80	20	308	154	103	77
70	30	533	262	176	132
60	40	821	410	274	205
50	50	1231	615	410	308
40	60	1778	941	615	457
30	70	2667	1455	941	727
20	80	5333	2462	1600	1231
10	90	10667	5333	4000	2667

Graph I

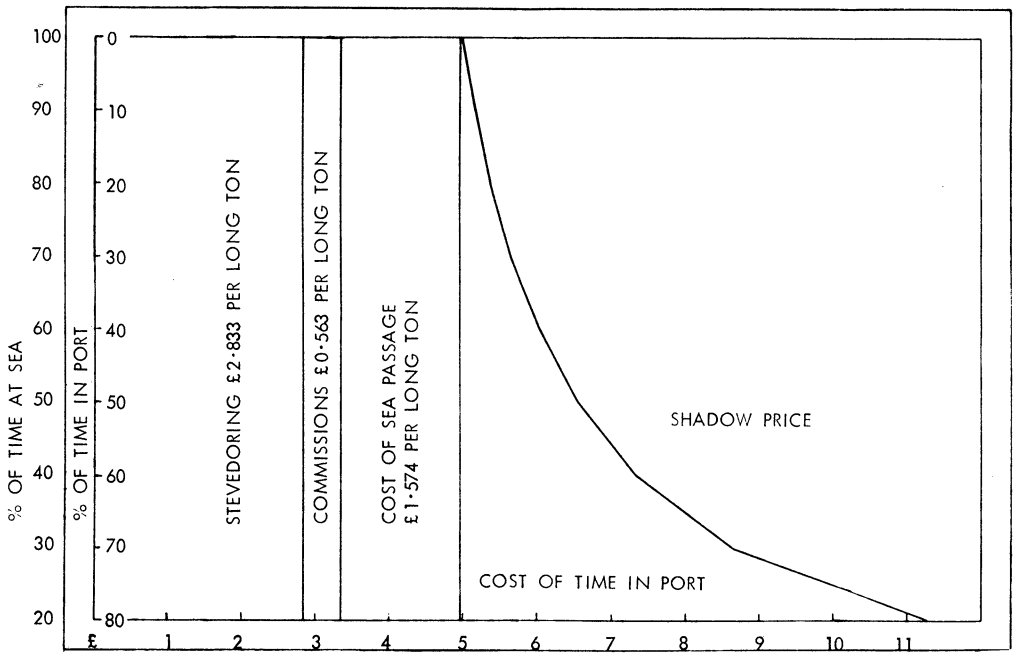


by plotting on a graph, or by calculating, the proportionate change in shadow price resulting from reducing the proportion of time spent in port. Graph I shows the whole of the data presented in Table II. Graph IIa repeats the shadow prices for a 10,000 n.m. round voyage and shows how each is comprised. Graph IIb again repeats the shadow prices and adds the various supplementary results of Table III. In Graphs I and IIb the shadow price calculated by discounting at 6% is shown by a continuous line, while the accompanying broken line gives that obtained by calculating at 8%.

The proportionate changes in shadow prices resulting from altering the proportion of time spent in port are shown in tables Va (for 5,000 n.m.), Vb (for 10,000 n.m.), Vc (for 15,000 n.m.) and Vd (for 20,000 n.m.). Each of these tables may be read in the same way as a distance table, by entering at the top with the higher of the two proportions of time in port and taking that figure from the body of the table which lies in the appropriate column and in the line opposite the lower proportion of time spent in port. By reversing the process the tables may also be used for the effects of increasing the proportion of time spent in port.

It is possible to restate these findings in terms of the change in the shadow price for each day spent in port. A reduction of one day in port time, on the basis of calculation employed in this paper and regardless of route length, reduces the shadow price by about £0·121 per long ton.

Graph IIa



10,000 n.m. PER ROUND VOYAGE SHADOW PRICE 6%

Graph IIb

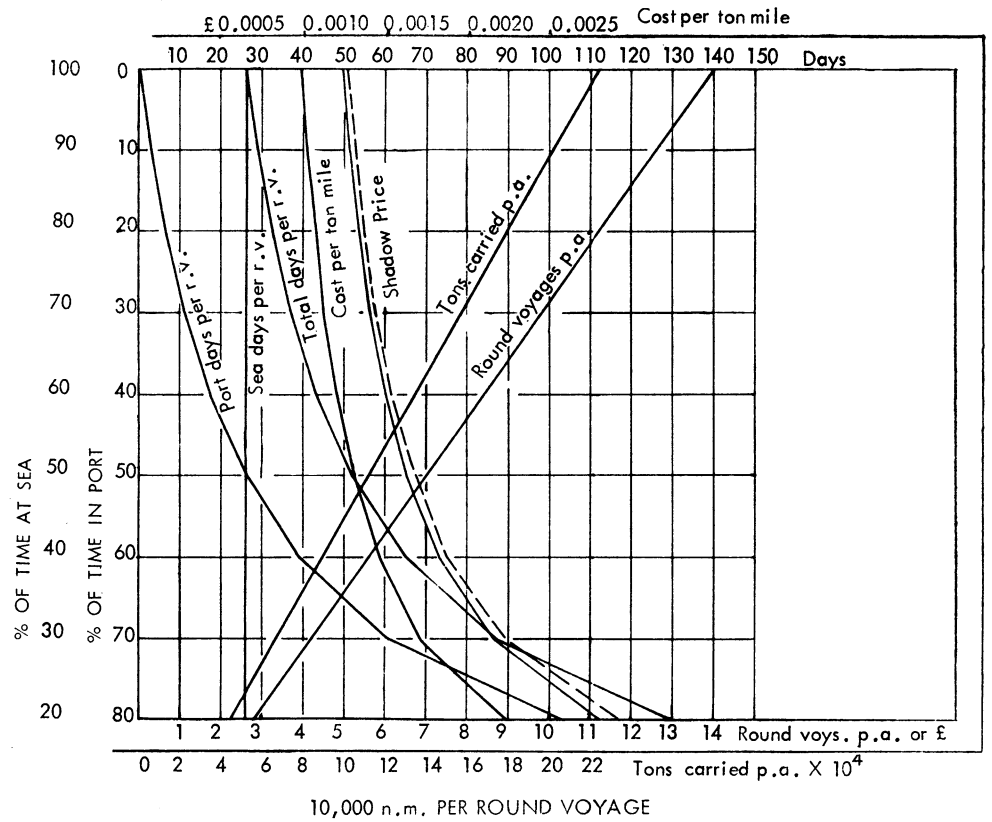


Table Va. Change in Shadow Price with change (6% basis) in Turnround (Percentage Reduction on 5,000 n.m. r.v.)

% of time in port	80	70	60	50	40	30	20	10	0
80	0								
70	17·9	0							
60	26·7	10·7	0						
50	32·0	17·2	7·2	0					
40	35·5	21·5	12·0	5·2	0				
30	38·1	24·6	15·6	9·0	4·0	0			
20	40·0	26·9	18·1	11·8	6·9	3·1	0		
10	41·5	28·8	20·2	14·0	9·3	5·5	2·5	0	
0	42·7	30·2	21·9	15·8	11·2	7·5	4·5	2·1	0

Table Vb. Change in Shadow Price with change (6% basis) in Turnround (Percentage Reduction on 10,000 n.m. r.v.)

% *of time in port*	80	70	60	50	40	30	20	10	0
80	0								
70	23·3	0							
60	34·9	15·2	0						
50	41·9	24·3	10·8	0					
40	46·5	30·3	17·9	8·0	0				
30	49·9	34·7	23·1	13·8	6·3	0			
20	52·4	38·0	26·9	18·0	11·0	5·0	0		
10	54·3	40·4	29·7	21·3	14·5	8·7	3·9	0	
0	55·9	42·5	32·2	24·0	17·4	11·9	7·3	3·5	0

Table Vc. Change in Shadow Price with change (6% basis) in Turnround (Percentage Reduction on 15,000 n.m. r.v.)

% *of time in port*	80	70	60	50	40	30	20	10	0
80	0								
70	25·9	0							
60	38·9	17·5	0						
50	46·7	28·0	12·7	0					
40	51·9	35·0	21·3	9·8	0				
30	55·6	40·0	27·3	16·7	7·7	0			
20	58·3	43·8	31·9	21·9	13·4	6·2	0		
10	60·5	46·7	35·4	26·0	18·0	11·1	5·2	0	
0	62·2	49·0	38·2	29·2	21·5	15·0	9·4	4·3	0

Table Vd. Change in Shadow Price with Change (6%basis) in Turnround (Percentage Reduction on 20,000 n.m. r.v.)

% *of time in port*	80	70	60	50	40	30	20	10	0
80	0								
70	27·6	0							
60	41·3	18·9	0						
50	49·6	30·3	14·0	0					
40	55·0	37·9	23·3	10·8	0				
30	59·0	43·3	30·1	18·6	8·8	0			
20	61·9	47·4	35·1	24·5	15·3	7·2	0		
10	64·2	50·5	39·0	29·0	20·4	12·8	6·1	0	
0	66·0	53·1	42·1	32·7	24·5	17·3	10·9	5·1	0

CONCLUSIONS

It is obvious from the foregoing that changes in turnround times exert a marked effect upon the cost of sea transport by cargo liner. The available evidence,[7] admittedly sparse (for there are no regularly published statistics of this important determinant of ship efficiency), suggests that cargo liners commonly spend about 60% of their time in port, and the near-unanimity of the cited references on this point is impressive.

The reference to New Zealand also suggests that, at least in that country, only 15% of the total time in port was occupied in working cargo; the remainder consisted of weekends, nights when cargo was not being worked, and periods spent awaiting a berth, awaiting cargo or suffering from breakdown (and in roughly that order of importance). Moreover, this 15% refers to "winch time" – *i.e.* when cargo is being worked at *any* hatch in the ship. Since cargo liners have several hatches, a proportion of this 15% must refer to periods when the cargo-handling ability of the ship was being used well below capacity. (Facilities are much the same at each hatch, and adjacent hatches do not normally interfere with one another; thus the law of diminishing returns does not apply in this context, at least up to the point when all hatches are being worked at full straight time.) If we assumed that this 15% winch time is equivalent to 10% of full capacity cargo-working, it would follow that, while 60% of the ship's time was spent in port, only 6% of the year was spent in loading and discharging cargo at full-capacity cargo-handling equivalent. In other words, half the average ship's life was spent doing nothing in particular, and the largest single reason for this was the limitations on actual working hours.

It follows that, even allowing for a certain amount of wasted time, it is quite possible that the 60% of the year now spent in port by the average cargo liner could be reduced to 20%,[8] thus doubling its annual carrying capacity. The resulting reductions in shadow prices (from Tables Va, b, c and d) are shown in Table VI.

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[7]See, e.g. *U.N. Monthly Bulletin of Statistics*, Sept. 1954 (64·4%); O.E.E.C. Maritime Transport Committee *Annual Report* 1954 (58·9%); R. M. Thwaites: "The Economics of Ship Time", *Trans. N.E. Coast Inst. of Engineers and Shipbuilders*, Jan. 1959 (60%), from which figures were taken for the *Report of the Committee of Inquiry into the Major Ports of Great Britain* (Rochdale Report) Cmnd. 1824, 1962, at p. 112; Producers' Boards Shipping Utilisation Committee and New Zealand Trade Streamlining Committee: *New Zealand Overseas Trade; Report on Shipping, Ports, Transport and Other Services*, New Zealand and London, 1964, para. 97 (56.4 to 61·2%); Speech by D. F. Martin-Jenkins reported in the *Chamber of Shipping of the U.K. Annual Report* 1965/6 (59·1%) and speech by Sir Nicholas Cayzer to the 11th A.G.M. of the British & Commonwealth Shipping Co. Ltd. on 27 July 1966 (58%). Lane (*op. cit.*) cites figures for the Australia-U.K. trade of 65·7% for 1951 and 59·1% for 1955. Only a small proportion of this is occupied in going into and out of port or in delays caused by weather.

[8]A pre-war example of remarkable success in this field was referred to by the late W. MacGillivray in "Speed at Sea and Despatch in Port", *Trans. Royal Inst. Naval Architects*, July 1948, where he recorded how, because of a breakdown, three ships had maintained a service which normally required four, and had continued doing so for some months. Three-shift working was adopted and some 14,000 tons of cargo were, on many occasions, handled in three days. This included time spent in shifting berth, and may, therefore, be regarded as equivalent to about 5,000 tons per day. This r ate, which was achieved with ships built in 1929, is much higher than all the rates implied in this paper at proportions of time in port in excess of 10%, except on the 5,000 n.m. route.

Table VI. Reductions in shadow price by reducing time in port from 60% to 20%

Round voyage distance	*Reduction in shadow price*
n.m.	%
5,000	18·1
10,000	26·9
15,000	31·9
20,000	35·1

The (unweighted) average of the reductions shown in Table VI is 28%.

It was assumed earlier that cargoes would continue to be available at the same freight rates. If the effect of faster turn-round was that the ships in question were laid up, there would be no saving of capital costs and the calculations of shadow prices presented here would be misleading. But we can reasonably assume that the more efficient use of a ship or ships on one route displaces the least efficient ship employed anywhere into lay-up. (Ships are generally marginal substitutes for one another, except that dry cargo carriers are not substitutes for tankers – an irrelevant point in the present context.) The least efficient ship employed (the marginal ship) will be making negligible gross profits[9] and, therefore, will have running costs equal to those of an intra-marginal ship, plus whatever gross profit that intra-marginal ship is making minus the (negligible) lay-up costs of the marginal ship. Assuming ships to be at least marginally mobile between routes, the savings to be obtained for improving turn-round are therefore real resource savings, and in practice these resources (*e.g.* the seamen) have alternative employments. This assumption would become invalid only if there were so remarkable *and unexpected* an improvement in turn-round times (*e.g.* on many routes at the same time) as to affect the general supply/demand position of world shipping (*e.g.* by precipitating a large increase in laid-up tonnage).

The shadow price reductions shown in Table VI, of course, take no account of any increases in factor prices which might result from more intensive working. It is entirely possible, however, that any extension of working hours would lead to higher earnings (it is probable that shift-working by the dock labour employed in cargo handling would only be undertaken in exchange for significantly increased earnings to compensate for the disruption of home life and leisure activities). It would then be necessary to consider whether the net effect of improving turnround on the one hand and of experiencing higher dock labour costs on the other hand is still a reduction in shadow price and, if so, how great that reduction would be. Unless multiple shift working led to a significant reduction in productivity (*i.e.* tons of cargo handled per man-hour) – this is perhaps unlikely because current working hours often contain a great deal of overtime and, with the hard physical effort involved in break-bulk cargo-handling techniques, it is doubtful whether any greater tonnage is handled in a man-day of ten hours than in one of eight hours – or unless the reduction in shadow prices led to a reduction in freight rates sufficient to increase the quantity of goods

[9]Compare Shotaro Kojima: "The Effects of Shipping Competition on Freight Rates", *Kyoto University Economic Review*, July 1927, and A. Strmøme Svendsen: "Factors Determining the Laying-up of Ships", *Shipbuilding and Shipping Record*, 19 June 1958.

transported by sea, there would be no need to alter the size of the labour force employed.[10] But the reductions in shadow prices shown in Table VI are so great that, although the largest single item in the present structure of costs (as divided into the conventional shipping accountancy headings shown earlier) is cargo-handling, and although this consists largely of wages, almost incredibly large shift premia would be necessary to negate those reductions.

Multi-shift working (and it should not be supposed that this is the only way of improving the turnround of cargo liners) may, of course, lead to difficulties in warehousing and inland transport. Railways often operate continuously but at most general cargo ports only a minor proportion of liner cargo now arrives or departs by rail. Road transport is much more difficult to operate continuously, and even if this could be arranged it would be impossible to allow for continuous departures from, or arrivals at, inland points unless the originators or recipients of the cargo themselves worked multiple shifts. This is primarily a problem of coping with short-term lags and bottlenecks; it obviously warrants further study of, for example, the opportunities of organising modern sorting, warehousing and calling-forward techniques and facilities, so that the delays in transfer of cargo between inland transport and dockside do not impede the more rapid transfer of cargo between ship and quay.

This paper has considered no more than the effects on shadow prices of altering the turnround performance of conventional cargo liners, of which (especially in the British-registered fleet) so many have been built in recent years. It has not compared the actual or potential performance of such ships with alternative techniques – such as those involving pallets, containers and roll-on, roll-off – on which many papers have been published in recent years. Some remarkable results have been reported – *e.g.* the simultaneous achievement of an 80% improvement in turnround time (from 5 days to 1) and a 90% reduction in stevedoring man-hours by changing from conventional to all-container operations. But such a change requires the purchase of many hundreds of containers (at £500 to £800 each) and the construction of specialised ships which, in general, cannot carry any substantial quantity of cargo not in containers (because the quayside movement of containers is parallel to the ship's fore-and-aft line and that of conventional break-bulk cargo at right angles to it). Such remarkable results can, in other words, be achieved only as a result of large capital expenditures, and then only in respect of a (possibly large) part of the total cargo moving in cargo liners.

It may, therefore, be suggested that comparisons between container operations (or other advanced cargo-handling techniques) and conventional cargo liners should not assume a continuation of past or present performance of the latter. This, however, is not to suggest that container, pallet and roll-on, roll-off techniques are uneconomic, or that they have not an important place in sea transport: merely that the great advantages they offer should be compared with the performance of conventional ships and techniques *after* any likely improvements in the latter have taken place.

London

[10]Fewer berths would be needed for the same annual throughput of cargo at the port; thus work could be concentrated on the most efficient berths. For an expanding cargo throughput less capital investment would be needed.