A COST BASED SIMULATION ANALYSIS OF SOUTH EAST ASIA - AUSTRALIA LINER SHIPPING

F.D. Gallagher[(1)] S.J. Meyrick[(2)]

(1) F.D. Gallagher
Director: Sea and Air Policy
Department of Transport
Perth, Western Australia, 6000

(2) S.J. Meyrick
Senior Transport Planner
Department of Transport
Perth, Western Australia, 6000

Introduction

This is a very much condensed version of a paper published as one of a series of ASEAN-Australia Economic Papers.[(1)] The series of papers is part of the output of the ASEAN-Australia Economic Relations Research Project. The Project was jointly sponsored by the Governments of Australia and the six ASEAN nations. It was funded by the Australian Government and was undertaken between 1981 and 1985.

This paper is concerned with the development of a cost based simulation model, and the application of the model to the liner shipping services which link South East Asia and Australia.

The model is concerned with what economists call technical efficiency in liner shipping. Consequently, it is concerned with all of the costs of supplying liner shipping services rather than the prices or freight rates charged to shippers.

The paper can be regarded as being made up of two parts.

The first part of the paper deals with the development and specification of the model. It also deals with the model's basic input, the physical and cost data generated by reducing the Existing System of liner shipping services between South East Asia and Australia to a stylised form, thus making it amenable to analysis.

The second part of the paper deals with the simulation model's output. That output allows us to explore and analyse economic behaviour in the Existing System. The output also allows us to identify a range of alternatives to the Existing System and to analyse those options which seem superior to it in some way.

PART 1
Model Description

The choice/costing model does not incorporate a formal algorithm designed to locate and define the best possible pattern or system of liner shipping services. Nor does it attempt to assess the cost of operating any given pattern of services in an ideal world. The model has been designed to mirror the limitations which a fragmented decision-making process and imperfect price signals impose on the minimisation of the total costs associated with any given shipping pattern. It also provides the researcher with the information on system performance necessary for him to adopt an intelligent heuristic approach to the exploration of alternative routes to more cost efficient ways of performing a given liner shipping task[(2)].

Conceptually, the operation of the model can be partitioned into six self-contained tasks:

1. Definition of a shipping system.

2. Estimation of cargo carrying capacities and service frequencies.

3. Allocation of cargo amongst shipping alternatives according to user-choice rules.

4. Comparison of the 'preferred' cargo pattern with cargo-carrying capacity, and, if necessary, modification of the cargo pattern to conform to capacity constraints.

5. Costing of the shipping system.

6. Examination of the allocation pattern to detect the existence of excess capacity in the system.

Figure 1 illustrates the way in which these modules are combined in a complete application of the model.

<u>Phase 1</u> Definition of the Shipping System

The supply side of the shipping system is fully described by identifying each operative vessel and the route it plies. In reality, each ship may be slightly different and each route distinct. In order to reduce the problem to manageable proportions, the system must be stylised to some extent. This process of stylising the system is described in greater detail in the next section headed "Stylising a Liner Shipping System".

<u>Phase 2</u> Estimation of service frequencies and cargo carrying capacity

In reality, since loading and unloading times form a significant proportion of round trip times, service frequencies are a function of the way cargo is allocated among the various vessels in the liner shipping system. At this early stage of the model flow, however, the way cargo will be allocated, within the liner shipping system option then being simulated, is not and, indeed, cannot be known. It is therefore necessary to make a number of more-or-less arbitrary assumptions in order to obtain initial estimates of round-trip times, and hence of frequencies.

The principal assumptions in obtaining initial estimates of service frequencies were:

i) the average overall load factor on all ships was taken to be 0.80

ii) irrespective of the number of ports of call, two complete cycles of cargo loading and unloading were performed during each round trip

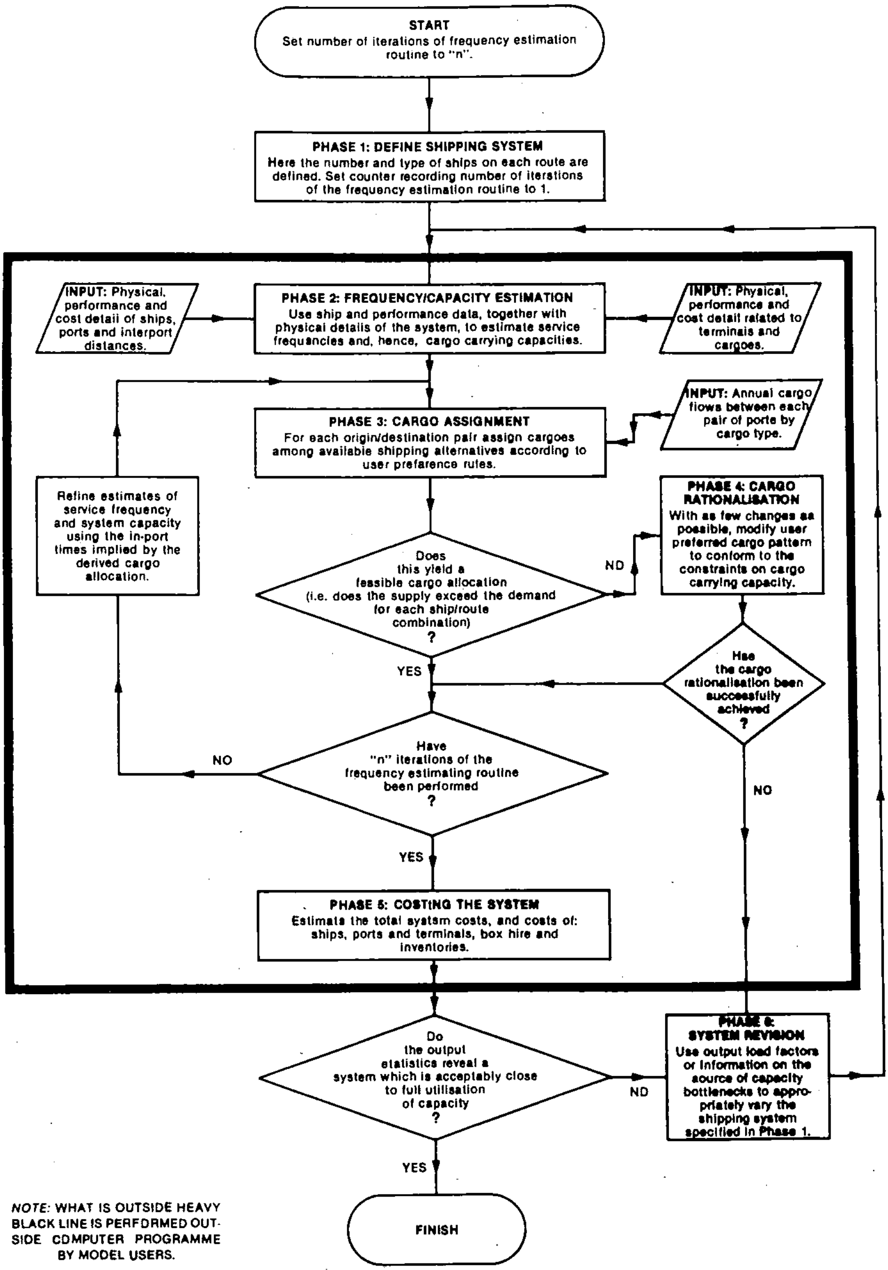
iii) the extent of loading and unloading was the same within each port group.

Under these assumptions, a ship calling at four port groups would load and unload 40 per cent of its cargo carrying capacity within each port group. A ship calling at two port groups, on the other hand, unloads 80 per cent of capacity within each group.
The calculation of the initial frequency (and hence capacity) estimates was then straightforward.

<u>Phase 3</u> Allocation of cargo using user-choice rules

The fundamental assumption underlying the estimation of preliminary cargo assignment was the usual one of economic rationality: shippers will attempt to minimise the costs they face. Their costs consist, essentially, of freight rate and inventory costs. The assumption was made that, for any given shipper, the rate charged by liner services will be governed only by the origin, destination, and type of cargo: that is, it will be independent of the ship type and route. The problem, from a shipper's perspective, then reduces to one of minimising inventory costs: put simply, the shipper will attempt to get his cargo aboard that ship which gets it to its destination at the earliest date.

FIGURE 1 Flow Chart: How Analytical Simulation Model Works



Each shipper has available to him a finite set of alternatives for shipping his produce. Let there be 'm' possible ships which he could use. Then the chance that he will use any particular ship 'k' can be represented as a function of two sets of variables:

$a_j \ldots,\ j = 1,\ldots, k,\ldots m$,	the time before ship 'j' arrives in the origin port,
and $T_j \ldots,\ j = 1,\ldots, k,\ldots m$,	the transit time between the origin and destination ports for that ship.

The shipper's decision must be made on the basis of expectations of transit times, since he does not know in advance the actual time. For this reason, it is not unreasonable to treat T_j as a determistic value, based on either published shipping schedules or past performance, rather than a random variable. We can make the further reasonable assumption that T_j is the same for all ships '1' which are of the same type and which ply the same route. This allows us to model the choice decision as one between groups of ships, 'k', rather than between individual craft, where each group is comprised of a set of ships of a specified type on a given route. In this formulation, a_j is the time before the next ship of group 'j' arrives in the origin port. In conformity with the inventory cost minimisation hypothesis, the shipper will prefer alternative 'k' if

$$a_k + T_k < a_j + T_j \quad \text{for all } j,\ k \tag{4}$$

The distribution of the random variables a_j will be determined by the assumptions made about the distribution of ship arrivals, and the interrelation between the production of the commodity to be shipped and shipping schedules. For the distribution of arrival headways within each group, an independent negative exponential function was assumed.

On the basis of these assumptions, we can derive an expression for the probability that any specific alternative 'k' is chosen. If E_k is the event that alternative 'k' is chosen, then

$$\begin{aligned} \text{Prob}(E_k) &= \Pr(a_j + T_j > a_k + T_k) \text{ for all } j \neq k \\ &= \Pr(a_j > a_k + T_k - T_j) \end{aligned}$$

1. Shipping lines make the minimum possible number of changes to the desired cargo allocation.

2. Shipping lines are more prepared to modify shipping arrangements for low-value cargoes than high-value cargoes.

3. Shipping lines will attempt to get re-assigned cargo on-board ship at the earliest possible date. This concern is, albeit imperfectly, in the re-allocation model by re-assigning to the highest frequency service having excess capacity.

The rationalisation process can then be represented as a linear programming problem. The objective function is to minimise the quantity of cargo re-assigned, and the constraints are that capacities must not be exceeded, all cargo must be shipped, and all assigned volume non-negative. The cargo allocation pattern obtained from the "user-choice" phase is then an optimal (the volume of cargo re-assigned is zero) but infeasible (some capacity constraints are violated) solution to this problem. The dual simplex method[3] is employed to move from this starting solution to the best feasible solution - our 'rationalised' cargo pattern.

Phase 5 Estimation of costs

Having found the final assignment pattern, the estimation of costs is straightforward if somewhat intricate. The original estimates of pre-embarkation cargo delays during the preliminary assignment phase are updated to accommodate the revisions to the assignment pattern effected in Phase 4. Given the complete cargo assignment and revised pre-embarkation delays, it is then possible to estimate the total delay incurred by each unit of cargo, and the number of days each ship spends in port and at sea. This is the essential information required to perform a full costing of the hypothetical shipping system.

Phase 6 Revision of the shipping system specification

As has been said, this phase is performed manually. An incidental output of the costing module is a load-factor table, which indicates the extent to which available cargo capacity is utilised on each ship type on each route. This table was used in conjunction with subjective judgment to create promising revisions to the specified shipping system.

Stylising a Liner Shipping System

The sort of simulation analysis undertaken in the study required, as well as a realistic behavioural model of a liner shipping system, the creation of a stylised version of an existing liner service (or set of liner services). This allowed sensible input to be generated for the model and provided an appropriate context for comprehensible interpretation of model output.

The method of stylisation closely reflects reality but generalises the workings of a system of liner shipping services so as to eliminate a mass of detail and marginal variations in input parameters which are not relevant to analysis of key economic variables in the system. It does this through two significant devices: pooling ports into a small number of geographically contiguous groups, thus reducing greatly the number of origin/destination points and route alternatives; and dividing liner services into 'Closed System' and 'Open System' services and devising rules for partitioning between the two. Rules have also been devised for definition of the cargo task, selection of appropriate ship types, operation of the ships, and utilisation of ship capacity. The stylisation allows sensible input data to be generated for the simulation model, and it provides an appropriate context for interpretation of model output.

Port Groups:

Pooling of ports is an important feature of the simulation analysis. It enabled us to keep the number of origin and destination points in the analysis down to a small and manageable number. In the stylised version of the liner shipping trades linking Southeast Asia and Australia, there are only four origins and destinations or port groups. These are code named SMIT, HKTP, ECA and WCA. Their relative locations are shown in Figure 2.

A set of characteristics of shipping line behaviour was defined for each of these four port groups. In the simulation analysis, these stylised characteristics are assumed to be constant for all vessel round trips simulated by the working model. The characteristics are described in Table 1, below, and illustrated in Figure 2.

TABLE 1
SOUTHEAST ASIA-AUSTRALIA LINER SHIPPING SIMULATION:
CHARACTERISTICS OF PORT GROUPS

Code name	Area description	Number of ports in Group	Sailing distance within Group (nautical miles)	Entry/exit ports
SMIT	Singapore, Malaysia, Indonesia, Thailand	4	1290	Jakarta and Singapore
HKTP	Hong Kong, Taiwan, the Philippines	3	885	Hong Kong and Manila
ECA	East coast of Australia	3	1100	Brisbane and Melbourne
WCA	West coast of Australia	1	nil	Fremantle

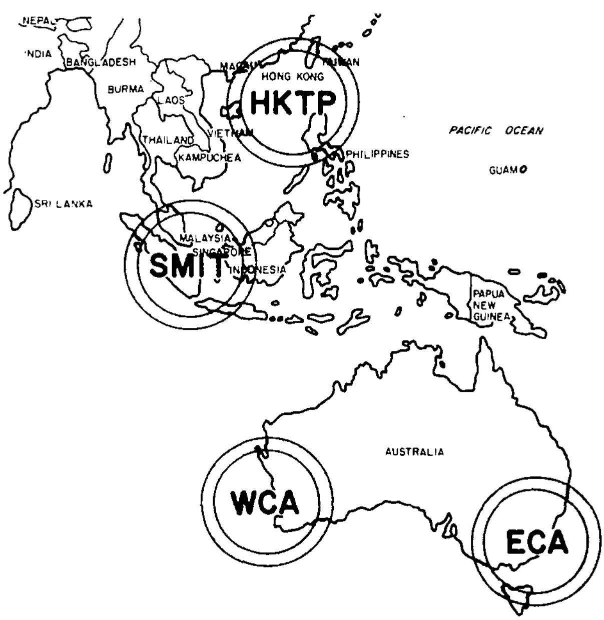


FIGURE 2 Southeast Asia-Australia Liner Shipping Simulation: Relative Locations of Four Port Groups

To reflect the realities of the Southeast Asia-Australia liner trades, it was necessary to stylise what we called "Closed System" and "Open System" services. In the "Closed System", liner service vessels could call at ports in Australia, in the ASEAN region and in Hong Kong or Taiwan, BUT nowhere else. In other words, within a "Closed System", no ship would operate on a route which did not connect ports in Australia to ports in SMIT and/or HKTP (see Table 1). In the "Open System", liner service vessels could call at ports in Australia and ports in SMIT and/or HKTP as well as some ports outside that system. The working model could accommodate vessels operating in both the "Closed System" and the "Open System". The two systems existed side by side and cargoes were permitted to interchange freely between them.

At this point, it is worth noting that there are problems with using either a "Closed System" or an "Open System" approach to system stylisation. The "Closed System" approach avoids the need for weakening objective analyses by subjective and/or arbitrary cost allocations, but it does not adequately reflect reality. The "Open System" approach can adequately reflect reality, but it does introduce the necessity to introduce subjective and perhaps arbitrary cost allocations in relation to some, albeit a relatively small proportion of cargoes.

Cargo Task:

Stylisation of the cargo task with which the simulation analysis is essentially concerned was based on actual cargo movements in the early 1980s. The annual cargo task appropriate to the stylisation is set out in Table 2.

TABLE 2
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION:
ANNUAL CARGO TASK

Port Group	Australian Exports		Australian Imports	
	ECA Ports	WCA Ports	ECA Ports	WCA Ports
Cargo Type 1: Laden Reefer Containers ('000s TEU)				
. SMIT Ports	4.5	2.0	1.4	0.2
. HKTP Ports	9.0	1.3	0.2	0.0
Cargo Type 2: Laden Dry Containers ('000sTEU)				
. SMIT Ports	19.0	6.0	14.7	6.3
. HKTP Ports	36.9	3.1	53.6	5.6
Cargo Type 3: Timber Packs/Steel Packs(1) ('000s tonnes)				
. SMIT Ports	60	15	100	10
. HKTP Ports	186	10	15	2
Cargo Type 4: Break Bulk ('000s tonnes)				
. SMIT Ports	127	15	64	10
. HKTP Ports	115	10	29	1

(1) And other cargoes sent in similarly "unitised" form.

Note: The figures in this table are based on Australian Bureau of Statistics and Australian Department of Transport statistics on trade and cargo movements for 1980/81.

Ports and Terminals

For the purposes of the simulation analysis, voyage by voyage variations in cargo throughput at each port within a port group are irrelevant. On the spot research showed that it was realistic to assume that each port within a group will behave similarly in relation to the service given to liner ships. Consequently, the information contained in Table 3, below, provides the basis for calculations of the time liner service vessels spend in port during their round trip voyages.

TABLE 3
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION
ANALYSIS OF IN-PORT TIME

Type of port	Idle time[(1)] in each port	Time spent moving in and out of port	Containers: loading or unloading rate	Break bulk cargo: loading or unloading rate
	hours	hours	TEU/per working hr.	tonnes per working hr.
Australian ports	18	6	10	50
South East Asian ports	6	6	20	80

(1) The idle time estimate for Australian ports contains an allowance for waterfront strikes and stoppages.

Routes and Cargo Flows

The realities of the trade and transport systems being analysed demanded some basic rules for the definition of the route patterns which are basic to the very large number of alternative operating strategy options which can be catered for within the simulation model. Thus, the stylisation demands that:

- a route must link at least one South East Asian port group with at least one Australian port group;
- while a route may link the two Australian port groups, no cargo which relates to trade between the port groups code named ECA and WCA[(4)] can flow on the route; and
- if the route which directly links the two South East Asian port groups, code named SMIT and HKTP, priority must be given to cargoes flowing between South East Asia and Australia - nevertheless, any amount[(5)] of top-up cargo not related to those trades can flow between these two South East Asian port groups.

Applying this set of rules left us with fourteen possible "Closed System" shipping routes linking the four defined port groups.

It was necessary to devise some additional rules constraining shipping on "Open System" routes. These are:

- ships plying them can only enter and/or leave the South East Asia-Australia trades via an Asian port: that is via a port in groups SMIT or HKTP; and

- the link between the Australian and South East Asian port groups must be direct, and not via some port outside the stylised system.

Ships: Selection and Capacity Constraints

An essential feature of the stylisation was the selection of four ship types to undertake the identified cargo task. The four simulated ships were selected so as to cover the wide spectrum of ship types likely to be seen in a "Mid Sea" trade such as that between South East Asia and Australia.

The stylised ships were as follows:

- a "Strider" type, which is a small, flexible, and, to some extent, self-sustaining container ship with a ro-ro-ramp, and has capacity for 320 TEUs.

- a fully cellular conventional container ship, referred to as "FC700", with capacity for 700 TEUs.

- an "Anro" type medium sized vessel, which is not self-sustaining, but has ro-ro characteristics, has a stern ramp, can carry containerised, break bulk or unitised cargoes, and has capacity for 1225 TEU.

- a conventional "Break-Bulk" liner ship with capacity of around 10,000 dwt.

In the simulation it was necessary to limit capacity utilisation for any one of the four selected vessel types on any single leg of a round trip voyage according to a predetermined set of rules. These rules favoured some cargo types over others but ensured that, overall, no more than 85 per cent (by weight) of cargo carrying capacity would be utilised during any leg of a round trip voyage.

Costs: Considerations and Calculations

Essentially, the simulation analysis is concerned with two sets of costs and their interaction with one another. The two sets of costs are:

- the costs of supplying liner shipping services; and

- the costs to shippers of holding inventories of goods in transit.

Where liner services are technically efficient, shipping companies will be seeking to minimise the cost of carrying out a given cargo task and the shippers of that cargo will be seeking to minimise inventory costs.

The shipping industry convention of assessing costs on a daily basis was adhered to in calculating shipping costs, container costs and inventory costs. All costs are, as near as possible, relevant to the first half of 1982. All are expressed in Australian dollars using, where necessary, the exchange rates applicable at or near 1 January 1982. Where necessary, unit cost parameters were adjusted by an appropriate index to account for the effects of inflation.

Ship Costs:

Ship costs, set out in Table 4, relate only to the vessel itself. They do not relate to the cargo. They include the costs of acquiring ships, paying and feeding crews, repairs and maintenance, insurance, administration and overheads (mostly related to shore based management of ship operation) and fuel. The costs are worked out on a daily basis, but are based on a 350 day year. Thus, an allowance of 15 days a year is made for a vessel to be laid up.

TABLE 4
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION:
COSTS PER DAY FOR SELECTED VESSEL TYPES

Costs per Day	Vessel Types			
	Strider	FC700	Anro	Break Bulk
	$A	$A	$A	$A
. At sea	13,840	19,300	34,240	10,530
. In port	10,660	14,210	26,550	7,080

Port Costs:

Port costs include charges for the following: tug hire, pilotage, mooring, wharfage, berthing and unberthing, navigational aids and lights. They also include minor, almost incidental charges for things like water, electricity and garbage disposal services for ships in port. The port costs used in the simulation analysis are set out in Table 5 below.

TABLE 5
PORT CHARGES PER PORT CALL FOR
SELECTED VESSEL TYPES

Port Location	Vessel Types			
	Strider	FC700	Anro	Break Bulk
	$A	$A	$A	$A
. South East Asia	3,000	6,000	9,000	5,000
. Australia	6,500	11,000	15,000	9,000

Terminal Costs:

Port charges are a charge on the ship using a port, whereas stevedoring and terminal charges are a charge on the cargo. Because of this essential difference, it was necessary to separate port charges and terminal and stevedoring charges. The unit costs of loading and unloading cargo in the stylised system are set out in Table 6 below.

TABLE 6
TERMINAL AND STEVEDORING COSTS
USED IN SIMULATION ANALYSIS

Type of cargo	Loading or unloading costs	
	at Australian ports	at South East Asian ports
. Laden reefer containers	$A290 per TEU	$A120 per TEU
. Laden dry containers	$A290 per TEU	$A 85 per TEU
. Empty containers	$A120 per TEU	$A 60 per TEU
. Break bulk cargo	$A 17 per tonne	$A 7 per tonne

Container Costs:

Like terminal costs, container costs relate essentially to the cargo rather than the vessel which carries that cargo. Terminal costs, in aggregate terms, remain constant for a given transport task. However, container costs will vary from option to option simply because, for a given containerised freight task, the length of time during which individual cargoes remain loaded in containers will vary from option to option. In addition, some allowance has to be made in the cost calculation for the long periods of time containers are empty and/or idle.

For the stylised liner shipping system, daily hire costs of $A16 for an ISO standard reefer container and $A2 for an ISO standard dry container have been used. Daily container costs appropriate to the stylised system are:

Reefer containers	$A43.95 per TEU per day in transit
Dry containers	$A 6.38 per TEU per day in transit.

Inventory Costs:

The following representative values have been derived for commodities in each of the four categories relevant to this paper.

- Reefer containers - $A25 per FCL[(6)] per day
- Dry containers - $A12 per FCL per day
- Timber packs/steel packs - $A0-20 per tonne per day
- Break bulk cargoes - $A0-20 per tonne per day

PART 2
Output: The Existing System and an Efficient Alternative

The Existing System

The first objective of the simulation analysis was to analyse how the stylised version of the Existing System of South East Asia-Australia liner services copes with the cargo task identified in Table 1, when it is performing according to the behavioural rules set out in Part 1. The most essential output from applying this system of liner services to that cargo task, per medium of the simulation model, was that related to systemwide costs. Using 1981/82 cost data, the costs of performing the cargo task were estimated, by the simulation model, to be as follows:

. Ship costs	$A216.3 million	55.4%
. Loading and unloading costs	$A 80.5 million	20.6%
. Port charges	$A 14.7 million	3.8%
. Container hire costs	$A 17.7 million	4.5%
. Inventory costs	$A 60.8 million	15.6%
Total costs attributable to stylised 1981/82 cargo task	$A390.1 million	100.0%

Thus, the first and most basic output of the simulation model was an estimate of the total resource cost of moving liner cargoes between South East Asia and Australia during 1981/82. The estimate of $A390 million which yields an average of $A121 per tonne of liner cargo shipped.

Flexibility and User Choice

As explained in the discussion of the workings of the simulation model in Part 1, the closer one gets to the mix of ships and route patterns, which is optimal in terms of technical efficiency, the more user choice is constrained. Eventually, the point is reached where available cargo capacity is stretched so tightly that all cargo assignment is effectively in the hands of the shipping lines. This kind of strained situation is so lacking in flexibility that it does not credibly reflect reality. There are many near optimal alternative systems which retain enough flexibility to leave most cargo assignment decisions in the hands of shippers. In other words, there is little point in totally reversing our user choice maxim in the hope of cost gains of less than, say, 50 cents per tonne of cargo.

In the heuristic application of our simulation analysis approach to finding more cost efficient solutions, many combinations of ships and routes which offered much lower cost shipping than the Existing System were identified. While none of these were identified as optimal for the stylised version of the liner services, many of them were obviously reasonably close to optimal.

Option A:

The simulation model output for one of these more technically efficient alternatives has been selected for comparison, in this paper, with the output for the Existing System.

Option A, as it is referred to in this paper, is really a tightened up version of the stylised Existing System. The heuristic approach to simulation allowed the stylised Existing System to be gradually trimmed until all or most of the ships on both the "Closed System" and the "Open System" were operating at or near their defined cargo capacities on most route segments.

The most essential output from applying Option A to the stylised cargo task for 1981/82, per medium of the simulation model, was the following set of systemwide costs:

. Ship costs	$A182.2 million
. Loading and unloading costs	$A 80.5 million
. Port charges	$A 11.8 million
. Container hire costs	$A 19.8 million
. Inventory costs	$A 71.1 million
Total costs attributable to stylised 1981/82 cargo task	$A365.6 million

Comparing the Options:

Stylised versions of both the Existing System and Option A are compared, in summary form, in Table 7. In the table, the capacities and costs of the shipping fleets, which are required to carry out the same cargo task in the simulations of the operation of the stylised Existing System or Option A, are compared.

Table 7 presents evidence of considerable excess capacity in the South East Asia-Australia liner trades. The output for Option A suggests that the system could have been operated with three less vessels. From the evidence presented in Table 7, we would estimate that there was around 3,000 TEU of excess capacity in the trades during 1981/82. In tonnage terms, this excess amounted to the equivalent of around 35,000 dwt. across the liner service fleet. Table 7 also provides a measure of the extent of technical inefficiency in the South East Asia-Australia liner shipping system. In cost terms, the excess capacity in the shipping system is, on the basis of the Option A/Existing System

TABLE 7
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION
COMPARISON OF SHIPPING FLEETS IN EXISTING
SYSTEM AND OPTION A

Item		Liner Service Strategy	
		Existing System	Option A
- Vessels in "Closed System"			
	Number	22	19
Rated capacity	TEUs	21,350	18,520
	'000s dwt.	429	364
- Vessels in "Open System"			
	Number	17	17
Rated capacity	TEUs	11,195	11,195
	'000s dwt.	223	223
Fleet Operating Costs (1)			
- Attributable to defined cargo task	$A millions	216.3	182.2
- Attributable to SMIT/HKTP top up cargo	$A million	0.1	4.8
- Total	$A Million	216.4	187.0

(1) As they relate to the defined 1981/82 South East Asia-Australia liner cargo task.

comparison, estimated to be $A35 million per annum at early 1982 prices. Averaged across the total cargo task, this represented an unnecessary resource cost burden on shippers of around $A12 for each tonne of liner shipping cargo.

For each of the four cargo types used in system stylisation, the cost estimates pertinent to the consolidated freight bills which shipping lines present to shippers in the South East Asia-Australia liner trades, are compared, for both the stylised Existing System and Option A, below.

	Existing System per tonne	Option A per tonne	Difference per tonne
- Reefer containers	$A163	$A150	$A13
- Dry containers	$A103	$A 89	$A13
- Timber/Steel packs	$A 95	$A 83	$A11
- Break bulk cargo	$A 80	$A 71	$A 9

Output and Analysis: Economic Characteristics

The model was used extensively to explore the feasibility and efficiency of alternative shipping patterns and to investigate the responsiveness of total system costs to changes in key economic and physical parameters.

The simulation model explorations described in this paper relate to:

- increases in ships' speed;
- the costs of Australian crews; and
- variations in other ship operating cost parameters.

Increases in Ships' Speed:

An increase in a ship's speed brings about an increase in the rate of fuel consumption and, therefore, an increase in fuel costs. These cost increases would be offset by reductions in sailing time and, therefore, reductions in inventory costs and container hire charges.

The essential questions asked in applying the simulation model to this particular analysis were: would an overall increase in ships' speed replace Option A with a technically efficient option in which less vessels were required and, what would be the systemwide cost breakdown for this new option?

It was calculated that increasing vessels' service speed by 2 knots over the whole fleet would increase ship operating costs, per day at sea, as follows:

Vessel type	Cost increase
. Strider	+$A2,020
. FC700	+$A2,690
. Anro	+$A3,790
. Break/Bulk	+$A2,290

However, the simulation model showed that the 2 knot overall increase in service speed would increase service frequency to the extent that the designated cargo task could be completed with two less vessels than in Option A. The net results of these increases in fuel costs and decreases in required capacity are shown in Table 8.

TABLE 8
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION
SYSTEMWIDE CONSEQUENCES OF 2 KNOT INCREASE
IN SHIPS' SPEED

Item		Liner Service Strategy	
		Original Option A	Option A modified for 2 knot increase in ships' speed
Vessels			
- Vessels in "Closed System"			
	Number	19	17
Rated Capacity	TEUs	18,520	17,500
Costs		$A millions	$A millions
- Ship costs		182.2	180.5
- Loading/unloading costs		80.5	80.5
- Port charges		11.8	11.6
- Container hire charges		19.8	18.7
- Inventory costs		71.1	65.1
Total costs attributable to stylised 1981/82 cargo task		365.6	356.4

Source: Simulation model output.

What the figures in Table 9 indicate is that, while the nett effect on shipping costs from an increase in ships' speed would be minimal, there would be significant gains from savings in container hire charges (from quicker turnaround of containers) and shippers' inventory costs.

Australian Crews:

In Table 10, the daily costs pertinent to Asian and Australian crews are compared for the vessel types selected for the simulation analysis.

TABLE 10
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION
ESTIMATES OF COSTS PER DAY FOR ASIAN OR AUSTRALIAN CREWS
(as at 1.1.1982)

Cost Item	Vessel Types			
	Strider	FC700	Anro	Break Bulk
	$A	$A	$A	$A
Asian Crew				
. Wages, salaries and allowances	1,490	1,720	2,070	1,650
. Providoring	550	700	880	650
Australian Crew				
. Wages, salaries and allowances	3,710	4,310	4,890	4,000
. Providoring	750	950	1,200	870

In addition to the costs of paying and feeding the crew, there is another extraordinary cost item associated with manning vessels with Australian crews. Most vessels must be modified to meet the crew accommodation requirements laid down by Australia's maritime unions. These costs would amount to around $0.3 million per annum per vessel.

One way of providing an insight into the impact of Australian manning requirements on the competitive ability of ship owners and operators who sail under the Australian flag is to use the simulation model to estimate the relative shipping costs for two liner fleets, one crewed entirely by Asians and the other crewed entirely by Australians.

This comparison was made using both the stylised Existing System and Option A used as test cases. Output for the four model runs is compared in Table 11.

TABLE 11
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION
SYSTEMWIDE ANNUAL COST COMPARISON FOR
ASIAN/AUSTRALIAN CREW OPTIONS

Option	Ship operating costs	Total costs attributable to 1981/82 cargo task
	$A million	$A million
. Existing System		
Asian Crew	216.3	390.1
Australian Crew	248.0	421.8
. Option A		
Asian Crew	182.2	365.6
Australian Crew	209.9	392.9

Source: Simulation model output

From Table 11 it is apparent that operating the entire fleet of vessels with Australian rather than Asian crews would add between $A27 million and $A32 million to the cost of the resource inputs needed to carry out the defined cargo task. Expressed in these aggregative terms, these figures reveal very little about the trade. However, reduced to a unit cost basis, the figures give a fairly realistic indication of the cost penalty incurred when an Australian rather than an Asian crew is used: that is $A9 per tonne of liner cargo carried between South East Asia and Australia. On the basis of the simulation analysis, meeting all of the requirements of an Australian crew would add about 15 per cent to the costs of operating a liner ship in the South East Asia-Australia trades.

Increases in Other Cost Components:

The simulation model was used to examine the effects of 50 per cent changes in each one of the following ship operating cost parameters: fuel costs, administration costs, the rate of interest on capital, and the capital costs of acquiring ships (either by outright purchase or on long-term charter).

Fuel costs and interest rates were looked at because their costs have been highly volatile and subject to rapid change over the past decade. Administration costs were looked at because there may be a wide margin for error in the estimates used in costing the stylised version of the Existing System. The cost of acquiring ships was subjected to this sensitivity test because there can be wide variations in the capital costs of seemingly similar new vessels. Another reason for looking at acquisition costs was to apply some test to the assumption that all ships (except the break-bulk vessels) will be acquired as new ships and eventually replaced with new ships. In the real world of liner shipping, the purchase and chartering of secondhand (or thirdhand...) vessels is commonplace.

The effects of the 50 per cent cost increases on the daily costs of operating the four stylised vessel types are shown in Table 12.

TABLE 12
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION: 50 PER CENT INCREASES IN COMPONENT COSTS: EFFECT ON DAILY COSTS OF OPERATING VESSELS(1)

Cost Item	Vessel Types			
	Strider	FC700	Anro	Break Bulk
	$A	$A	$A	$A
Vessel acquisition(2)	2,500	3,250	8,750	1,250
Rate of interest on capital(3)	1,710	2,560	5,970	850
Administration/overheads	1,000	1,100	1,200	600
Fuel				
. at sea	2,214	3,169	4,780	1,950
. in port	625	625	935	225

(1) Refer to cost data in Table 4.
(2) Cost of purchasing or chartering ship.
(3) Cost of borrowed capital and/or opportunity cost of equity capital.

It is apparent from the figures in this table that vessel acquisition costs and the cost of fuel are relatively sensitive variables. Changes in them are likely to have a significant impact on total ship operating costs. To gauge the effect of variations in these cost items on the relative costs of system-wide resource inputs, it is necessary to look to the output of the simulation model. In Table 13, the effects of 50 per cent variations in the costs of these four items are illustrated for the stylised Existing System and for Option A.

Two comments are needed to elaborate appropriately on the figures presented in Table 13. First, while total costs are not as sensitive to changes in fuel prices as they are to capital associated costs, the costs of fuel have proven to be much more volatile than the costs of other resource inputs. A 50 per cent increase/decrease in fuel costs should be looked at in the context of fuel price increases in recent years. Between 1974 and 1981, the (actual) price of marine fuels increased by more than 1,000 per cent.

Secondly, the impact on total costs of a 50 per cent decrease in ship acquisition or charter costs would be similar to that of a 50 per cent increase in acquisition costs. Table 13 shows that a 50 per cent variation in vessel acquisition/charter costs can vary total system costs by around 12-13 per cent. This indicates that a ship operator who can acquire reliable ships cheaply will be very competitive. This is possible in the currently depressed charter market. Secondhand tonnage can be acquired at a fraction of the cost of newly built ships.

TABLE 13
S.E. ASIA-AUSTRALIA LINER SHIPPING SIMULATION: 50 PER CENT INCREASE IN COMPONENT COSTS: EFFECT ON TOTAL COSTS

Cost Component Subject to 50% Increase	Existing System		Option A	
	Total Attributable Cost	Proportional Increase	Total Attributable Cost	Proportional Increase
	$A million	%	$A million	%
Vessel acquisition(1)	443.1	13.6	410.4	12.3
Rate of interest on capital(2)	428.5	9.8	398.2	8.9
Administration/ overheads	399.8	2.4	373.9	2.3
Fuel	414.7	6.3	385.5	5.4

(1) Cost of purchasing or chartering ships.
(2) Cost of borrowed capital and/or opportunity cost of equity capital.

CONCLUSIONS

Our essential objectives were to briefly describe a cost based simulation model and demonstrate how it can be applied in the complex world of containerised liner shipping. We think that both of these objectives have been realised in this paper.

In addition, we would claim that the findings related to that small part of the model's output exposed in this paper illustrate another one of the advantages of simulation approach to economic analysis. The simulation model takes into account the workings of the whole transport system. Therefore, the analyst can view his findings on individual characteristics of the system in an appropriate perspective. Thus, for example, the economic impact of using Australian crews on ships is not judged in isolation from knowledge about other critical economic influences in the system.

In summary, the model output discussed in this paper revealed the following:

- During 1981/82, the South East Asia-Australia liner trades were overtonnaged. It is estimated that the system could have been efficiently operated with three less vessels, without imposing serious constraints on shippers' choices of vessel. Averaged across the total cargo task, this over tonnaging represented an unnecessary resource cost burden on shippers of around $A12 per tonne.

- While the nett effect of an increase in ships' speed on the resource costs of undertaking a fixed liner cargo task would be minimal, there may be significant gains to shippers from savings in container hire charges and inventory costs.

- It is estimated that the cost penalty incurred when an Australian rather than an Asian crew is used is $A9 per tonne of liner cargo carried on a vessel operating between South East Asia and Australia. Meeting all of the requirements of an Australian crew would add about 15 per cent to the costs of operating the ship. As there are only three vessels in the South East Asia-Australia liner trades which have Australian crews, the impact across the whole cargo task is not very great. Use of Australian crews on these vessels adds less than $A1 per tonne to the resource cost of carrying out that task.

- A 50 per cent overall variation in vessel acquisition or charter costs would vary total system costs by around 12-13 per cent. This indicates that the system is very sensitive to changes in the parameter and that a ship operator who could acquire reliable vessels cheaply would be very competitive. This is possible in the currently depressed charter shipping market. Secondhand tonnage can be acquired at a fraction of the cost of newly built vessels.

- A 50 per cent increase/decrease in bunker fuel costs would vary total system costs by around 5 per cent. It may be constructive to look at the sensitivity of the system of liner services to changes in bunker fuel prices in the context of fuel price movements over the past decade. Between 1974 and 1981 the (actual) price of marine fuels increased by more than 1,000 per cent.

NOTES:

(1) Gallagher, F.D. and Meyrick, S.J. (1984) 'ASEAN-Australia liner shipping: a cost based simulation analysis', ASEAN-Australia Economic Papers No. 12, ANU, Canberra.

(2) This was made possible by the fact that, by building consistent decision rules into the model, the non-integer components of the objective function - the cargo volumes and delays - could be derived from the values of the integer variables - the number and type of ships on each route. In conceptual terms, the definition of the shipping system would, given a set of decision rules, imply a particular allocation of cargoes between competing shipping services.

(3) See Taha, H.A., pp. 97 - 99.

(4) Cabotage of Australian coastal cargoes demands adherence to this rule.

(5) In effect, for simulation purposes, this means that an infinite quantity of top-up cargo can flow , in either direction, between the port groups SMIT and HKTP.

(6) FCL means Full Container Load - typically, around 15 tonnes of cargo.

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