The Economics of Increasing Speed in Sea Transportation: The Case for the Southern U.S., Mexico, Central America and the Caribbean

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From a business perspective, the most important and strategic transportation decision is the choice of transportation mode (Scott 1999). Transportation is the costly component of the total logistic function given the lengthy product pipeline necessary to support a supply chain from production to consumption. This decision becomes more important in international trade of high-value and time-sensitive/perishable (HV& TS/P) commodities, given their high cost and short product life.

Air and ocean transportation are the most common and relevant modes in international trade, especially when long distances are involved. Air shipping is fast, reliable, and allows businesses to keep less inventory in stock, but it is costly. Ocean shipping costs less but requires larger inventories to buffer against uncertainties such as spoilage and inventory loses, variations in transit time, and finance cost (Ganeshan and Harrison 1998). According to MergeGlobal, Inc. (2000) there is a modal gap between ocean and airfreight, given that some products that could be transported using an intermediate mode if one were available are being moved using the faster and more expensive mode even though it may not be required, since the alternative available mode is too slow; this consequently affects the cost of the goods being transported.

As indicated in a report on Public Ports Financing in the U.S. (USDOT 1994), Latin America (L.A.), Asia, and Africa are increasingly dominating international trade. With L.A. this trade growth has been intensified by export to the U.S. of perishables and non-traditional products such as flowers, melons, and shellfish, and import from the U.S. of machinery, raw materials (inputs), and consumer goods.

The steady increase in trade of HV & TS/P products has created an increased demand for cargo services to and from Latin American, in some cases (i.e. airfreight) creating a shortage of cargo space, hampered by inadequate infrastructure for handling perishable commodities (Putgzer 1998). Therefore, if U.S. exporters are to take advantage of these trading opportunities and realize the profit potential available in the international markets, they will need a responsive and cost-effective transportation service, which will require investment in new transportation and infrastructure technology for handling HV & TS/P commodities. However investments in new technology depend in part on that technology's potential profitability, which is necessary to compensate investors for their investment and risk.

This paper is intended to show that there is a potential for generating larger profits relative to conventional container vessels by investing in and implementing service routes with new transportation and cargo-handling technology like fast vessels and agile ports in the Southern U.S., Latin America, and Caribbean.

The Economics of Speed

In transportation, just like in most businesses, potential profit depends directly on revenue from selling goods or services and on the costs involved in providing that good or service. Both revenue and costs are related to the amount of cargo being transported in a given period. The traditional way to increase the movement of cargo units and therefore revenue in the maritime shipping business has been to increase vessel size, increasing cargo capacity per trip. The idea behind increasing vessel size has been to achieve economies of scale by spreading the cost of providing the service among a large number of cargo units. However, economies of scale have been achieved at the expense of a higher fixed cost associated with a large initial investment or sunk cost and larger operational risk due to a large fluctuation of demand in transportation services (Laine and Vepsäläinen 1994), an aspect that may be more relevant in the maritime services between the U.S.

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and Latin America.

An alternative, and perhaps a more flexible way to augment cargo capacity in the maritime businesses, is by increasing the number of round trips a vessel can make in a given period (e.g., one year). To increase round-trip frequency, the vessel's cruising speed and the cargo-handling speed at the ports must be increased. The technology to increase cruising speed involves improvements in hull design and in propulsion power. However, increased cruising speed is achieved at a relatively high fixed and operational cost, related mainly to a vessels construction and fuel-consumption costs (although with great flexibility given the smaller size of the vessels, which can adapt better to the fluctuating demand in transportation services) and to different speeds according to the seasonal demand for the service. Based on the economic theory, we can model the profit in shipping business as

$$\Pi = R - C$$
$$R = F_r \times Q_t f(R_f)$$
$$C = F_c + V_c f(R_f)$$
and
$$R_f = \frac{VO_d}{T_t},$$

where **Π** = potential profit, **R** = total revenue, **C** = total cost incurred by carriers to provide the service, $\mathbf{F_r}$ = freight rate, $\mathbf{Q_t}$ = quantity or number of cargo units (measured in forty-foot-equivalent units, or FEU) moved by a vessel in a trip, $\mathbf{F_c}$ = transportation fixed cost, $\mathbf{V_c}$ = transportation Variable cost, $\mathbf{R_f}$ = round-trip frequency, $\mathbf{VO_d}$ = vessel operational days per year, and $\mathbf{T_t}$ = round-trip time.

According to this model, the main factor that influences potential profit is round-trip frequency ($\mathbf{R_f}$), since it affects both revenue and cost. Higher $\mathbf{R_f}$ can be achieved by implementing fast vessels and agile ports to reduce transit time between ports. A high $\mathbf{R_f}$ is expected to affect revenue positively by moving a larger number of cargo units at potentially higher rates (relative to conventional freight rates, although still lower than airfreight), especially when HV & TS/P commodities are involved. Higher rates are justified by lower transit time and faster delivery, which reduces the probability of spoilage and reduces the cost of holding inventory while in transit, relative to conventional vessels.

Given these service advantages of fast ships and agile ports, there would an incentive for businesses to transport and store small quantities of goods (Stopford 1990) to keep inventory low, approaching a just-in-time delivery and inventory-holding system, which further reduces the financial inventory cost. $\mathbf{R_f}$ is also expected to have a positive effect on transportation cost by achieving economies of scale or spreading the fixed costs across a greater number of trips and consequently a larger number of cargo units. However as the number of trips per year increases, so too does the service variable cost, affecting the service total cost negatively. Therefore, as long as the positive effect of higher revenue resulting from higher rates and larger quantity of cargo units moved plus the reduction in cost from achieving economies of scale is larger than the negative effect from increasing variable cost, it is expected that $\mathbf{R_f}$ positively affects potential profit.

An important component of $\mathbf{R_f}$ is the vessel operational days ($\mathbf{VO_d}$), which is defined as the number of days per year in which the vessel is actively being used, either traveling between ports or loading or unloading at ports. For the purposes of this work, operational days are assumed to be 335, allowing 30 days per year for vessel maintenance and repair. The number of operational days divided by the $\mathbf{T_t}$ determines the number of potential trips a vessel can make in a year. $\mathbf{T_t}$ is the time it takes for a vessel to travel between 2 ports, including loading, unloading, and any other eventuality, and can be defined as

$$T_t = 2\left(\frac{D}{VS} + \frac{2(VC_r \times L_r)}{H_r} + \varepsilon\right)^{1}$$

where $\mathbf{T_t}$ = round-trip time, **D** = distance between ports in nautical miles, **VS** = vessel speed in knots, $\mathbf{VC_r}$ = vessel cargo-carrying capacity in FEU, $\mathbf{L_r}$ = vessel load rate as percentage of Vc, $\mathbf{H_r}$ = cargo-handling rate for loading and unloading at the ports in FEU/hr, and ε = random unproductive time, including pilotage, waiting time for loading/unloading, and any other eventuality.

According to Laine and Vepsäläinen (1994), in transportation we can make a distinction between productive and unproductive time during the round trip. **D/VS** represents the productive time, or time the vessel spends traveling between ports, which depends on distance and vessel speed. $\mathbf{2(VC_r \times L_r)/}$

[1] Adapted from Laine and Vepsäläinen (1994) and Seppälä (2002).

$\mathbf{H_r}$ represents the unproductive time, or time the vessel spends at port loading and unloading cargo, and is a function of vessel cargo capacity, vessel utilization rate (assumed to be 90%), and the port cargo-handling rate, (assumed to be 30 FUE/hr with existing load on/load off (Lo/Lo) port facilities, and 50 FEU/hr for agile ports). $\mathbf{(VC_r \times L_r)}$ is multiplied by two to reflect the loading and unloading activities in both origin and destination ports. In addition, the $\mathbf{H_r}$ with existing facilities is expected to vary between U.S. and foreign ports, and is assumed to be more efficient at U.S. ports, with 90% $\mathbf{H_r}$, and less efficient in foreign ports, with 80% $\mathbf{H_r}$. With agile port facilities the $\mathbf{H_r}$ is assumed to be the same in foreign and U.S. ports, 95% $\mathbf{H_r}$. ε—which is expected to be higher with current port facilities than with agile port facilities—is assumed to be 3.5 hours at each port.

Past literature and research has focused on increasing propulsion power as the main method of increasing displacement speed and round-trip frequency in maritime shipping business; however, increasing displacement speed while maintaining the current Lo/Lo port cargo-handling technology is equivalent to "hurry up and wait" since this technology may not be able to speed up the loading and unloading process for fast vessels, consequently increasing round-trip time. Therefore, in order to take full advantage of displacement speed and achieve a higher round-trip frequency, it is also necessary to invest in agile ports with dedicated terminals and suitable cargo-handling technology for fast vessels, technology that would reduce the loading/unloading time and increase round-trip frequency.

Fast Vessels and Agile Ports

There are a large number of fast-vessel designs available, some in the operation/testing stage and others on the drawing board. These vessels have a speed range between 28 and 60 knots, and a capacity range between 1500 and 33,500 MT. The selection criteria for the vessels considered in this study were based on the availability of reliable technical and cost data. Consideration also was given to a prior commercial and financial feasibility analysis for fast-vessel routes between the Southern U.S. and Latin America, according to Fuentes, Couvillion, and Allen (2003a). Table 1 presents some of the technical characteristics of the vessels considered in this work.

Agile ports consist of dedicated and specialized terminals for fast vessels with roll on/roll off (Ro/Ro) facilities, which require a considerable investment of 8 to 10 million dollars. These facilities would speed up the loading/unloading process and reduce container-handling costs to about $54/container, compared an estimated $71/container at to Lo/Lo facilities (National Ports and Waterways Institute 2000).

Table 1. Selected Vessels Technical Specification.

Vessel Technical Specifications	**Conventional Vessel**	**High Speed Mono-hull***	**High Speed Catamaran***
Overall length (meters)	183.6	161.7	112
Draft (meters)	6.6	7	3.6
Capacity (14.6 m trailers or 40' FEU[2] containers)	185.0	100	44
Crew size	8	14	9
Total power (kilowatts)	23,040.0	36,600	45,000
Main engines	4	2	2
Type of engine/propulsion	Diesel/ Propeller	Diesel/ Propeller	Gas Turbines/ Water Jets
Service speed in knots (at 100% MCR)	21.6	28	40
Fuel consumption at service speed (ton/hour)	4.6	6	9.9
Construction cost (U.S.$1997 M, adjusted for inflation)	$39,599,287		

Data and Application of the Proposed Model

The profitability in ocean shipping can be affected by displacement speed and cargo-handling speed. The analysis performed in this paper is done in two stages. In the first stage, the model is implemented to determine the potential profit for a dedicated (tramp) service between two selected ports in the Southern U.S., Mexico, Central America, and the Caribbean with the three vessels considered. In this first stage it is assumed that agile-port facilities to support fast vessels are not in place, and therefore the service must make use of the current Lo/Lo facilities. The use of these facilities will negatively affect port time, overall round-trip time and frequency, and ultimately the fast-ship-service profit.

In the second stage, profit is recalculated assuming the agile port facilities are in place, which would reduce port time, and increase round trip frequency for the fast vessels only. The conventional container vessel round trip frequency is not affected by changes to agile ports, since it is assumed that is not configured to make use of the agile ports facilities and therefore must continue using the current Lo/Lo facilities.

Transportation costs for the considered vessels was estimated according to Fuentes, Couvillion, and Allen (2003b). Data to estimate conventional container vessel transportation rates was gathered from a cargo forwarding company. Data was gathered for rates between different ports in the U.S. east and southeast region and Latin American ports. For routes where actual data was not existent, transportation rates were estimated using a linear regression of data on distances between ports and the GDP of different Latin-American countries, gathered from other studies.

Transportation rates for the fast vessels considered were estimated as a percentage of the estimated airfreight rate, ranging from 45% to 60% depending on the distance between ports and the estimated fast-vessel transportation cost between the Southern U.S. region and Latin America. Airfreight rates were calculated as an average of the charges per kilogram published by three airlines and a freight forwarder[2]. The estimations were based on an L-3 air-cargo-container specification with a capacity of 1588 kg. Loading/unloading charges and fuel surcharges (at a rate of $0.15/kg) were added to the cost per L-3 container to determine the total cost per container. This total cost divided by the container capacity determined the cost per kg, which was then multiplied by 1000 to determine the cost per MT and per FEU equivalent.

Simulation Results, Discussion, and Conclusions

The analysis presented in this paper indicates that it is possible to increase profit relative to a regular container vessel by implementing fast-ship routes that reduce the round-trip frequency for transporting high-value and time-sensitive or perishable commodities between the Southern U.S. and Latin America. However, in order to take full advantage of the potential profit-making opportunities the productive time must increase and the unproductive time must decrease, which calls for investments in technology that increases vessels' displacement speeds as well as in technology that speeds cargo handling at ports.

Table 2 presents transportation costs and freight-rates estimates for the different vessels and routes considered and calculated potential profits resulting from the model simulations. Results show that potential profit increases by an average of 104%, using the current Lo/Lo facilities relative to a slow-speed conventional container vessel (CCV). Agile ports increase HSC average profit by a further 53% to an average of 157%, with a range of 82% for low-frequency service to 229% for higher-frequency service, compared to Lo/Lo and CCV. HSC potential profit increases by an average of 21% by implementing Ro/Ro technology, relative to current Lo/Lo technology. If the HSM vessel is implemented, the average increase in potential profits is more moderate, with an average 70% increase, using the current Lo/Lo facilities relative to the slow CCV. Agile ports increase profits by a further 47%, to an average of 117%, with a range of 53% to 190% for low- and high-frequency service, respectively, compared to Lo/Lo and CCV. HSM potential profit increases by an average of 22% with agile port Ro/Ro facilities relative to Lo/Lo facilities.

Results show that the number of round trips increase by an average of 101% by implementing HSC routes with the current Lo/Lo facilities, relative to the slow CCS. When agile-port facilities are considered, $\mathbf{R}_f$ for HSC increases by a further 33% to an average of 134%, with a range of 123% to

[2] Northwest, United, Delta Cargo Airlines, and APX Cargo.

Table 2. Estimated Round-trip time and Potential Profit for a Fast Service Between Ports in the U.S. Gulf Region and Mexico, Central America, and the Caribbean for Considered Vessels.

		Gulf Port, MS						Miami, FL					
		Veracruz, México		Puerto Cortes, Honduras		Port of Prince, Haiti		Veracruz, México		Puerto Cortes, Honduras		Port of Prince, Haiti	
	Distance in Nautical Miles	771		854		1157		981		756		750	
Container Ship	Port cargo handling technology	Lo/Lo	Ro/Ro	Lo/Lo	Ro/Ro	Lo/Lo	Ro/Ro	Lo/Lo	Ro/Ro	Lo/Lo	Ro/Ro	Lo/Lo	Ro/Ro
	Estimated container rate/trip	$2,408	$2,408	$2,807	$2,807	$3,275	$3,275	$2,687	$2,687	$2,534	$2,534	$3,012	$3,012
	Container cost/trip	$1,601	$1,601	$1,697	$1,697	$2,048	$2,048	$1,844	$1,844	$1,584	$1,584	$1,577	$1,577
	Total trip time in days	4.5	4.5	4.8	4.8	6.0	6.0	5.3	5.3	4.4	4.4	4.4	4.4
	Round trips per Year	*75*	*75*	*70*	*70*	*56*	*56*	*63*	*63*	*76*	*76*	*76*	*76*
	Potential profit (M $)	*$10.05*	*$10.05*	*$12.89*	*$12.89*	*$11.45*	*$11.45*	*$8.88*	*$8.88*	*$11.98*	*$11.98*	*$18.19*	*$18.19*
	% Increase in potential profit			No Change						No Change			
High Speed Mono-hull (HSM)	Estimated container rate/trip	$4,901	$4,901	$5,240	$5,240	$5,512	$5,512	$5,731	$5,731	$4,804	$4,804	$4,746	$4,746
	Container cost/trip	$2,595	$2,375	$2,783	$2,563	$3,469	$3,249	$3,071	$2,851	$2,561	$2,341	$2,548	$2,328
	Total trip time in days	3.26	2.75	3.51	3.00	4.41	3.90	3.89	3.38	3.22	2.71	3.20	2.69
	Round trips per year	*103*	*122*	*95*	*112*	*76*	*86*	*86*	*99*	*104*	*124*	*105*	*125*
	% Increase in round trips/year	16%		15%		12%		13%		16%		16%	
	Potential profit (M $)	*$21.30*	*$27.66*	*$21.1*	*$26.90*	*$13.96*	*$17.49*	*$20.63*	*$25.71*	*$21.01*	*$27.41*	*$20.71*	*$27.09*
	% Increase in potential profit	23%		22%		20%		20%		23%		24%	
High Speed Catamaran (HSC)	Estimated container rate/trip	$9,018	$9,018	$9,528	$9,528	$10,357	$10,357	$10,421	$10,421	$8,902	$8,902	$8,898	$8,898
	Container cost/trip	$4,638	$4,343	$5,026	$4,731	$6,444	$6,149	$5,621	$5,326	$4,568	$4,273	$4,540	$4,245
	Total trip time in days	2.22	1.88	2.39	2.05	3.02	2.68	2.66	2.32	2.19	1.85	2.18	1.83
	Round trips per year	*151*	*178*	*140*	*163*	*111*	*125*	*126*	*145*	*153*	*181*	*154*	*183*
	% Increase in round trips/year	15%		14%		11%		13%		15%		16%	
	Potential profit (M $)	*$26.18*	*$33.02*	*$24.96*	*$31.02*	*$15,73*	*$20.81*	*$23.97*	*$29.19*	*$26.28*	*$33.25*	*$26.58*	*$33.66*
	% Increase in potential profit	21%		20%		24%		18%		21%		21%	

141% for low- and high-frequency service, relative to CCS. This result suggests that a 33% increase in average HSC $\mathbf{R_f}$ by implementing agile ports is associated with a 53% increase in average profit, relative to CCS. Increase in $\mathbf{R_f}$ with HSM vessel is more conservative, similar to the increase in potential profit. $\mathbf{R_f}$ increases an average of 37% using the current Lo/Lo facilities relative to the slow CCV. With agile ports, $\mathbf{R_f}$ for HSM increases by 23% to an average of 60%, with a range of 54% for the longer routes and 64% for the shorter route. This suggests that a 23% increases in average HSM $\mathbf{R_f}$ from implementing HSM and agile ports is associated with a 47% increase in average profit, relative to CCS.

In general, by implementing fast vessels, time spent at sea is reduced by 46% for the HSC and by 23% for the HSM, with the Lo/Lo facilities, relative to the container vessel. Time spent at port for HSC with agile ports is reduced from 59% to 82% of time spent in port for CCS with Lo/Lo facilities. For HSM, the port-time reduction resulting from agile ports is from 36% to 70% of time spent in port for CCS with Lo/Lo facilities.

These results and analysis also indicate that higher profits can be achieved with smaller vessels with higher speed, suggesting that there is a trade-off between vessel size or cargo capacity and speed. The difference in sea- and port-time reduction and the consequent increase in profit between HSC and HSM is attributable to the difference in speed and cargo capacity of the vessels. HSM, which has a larger cargo capacity and therefore the ability to move more cargo per year, has a slower speed than HSC, so it must spend more time at sea and at port for loading and unloading. This may have an impact on port congestion and longer port waiting time, especially on shorter routes, leading to losses of freight income and to profit reduction. Larger vessels also increase the operational risk, considering the fluctuations in demand for transportation services, making it difficult to maintain a high cargo-carrying rate during low-demand periods, reducing further profits due to losses in freight income while increasing operational cost.

This short analysis favors smaller vessels and suggests that ship size may have a higher impact on revenue, cost, and profit since small vessels would be able to travel faster and spend less time in port for loading/unloading, reducing the overall $\mathbf{T_t}$ and increasing $\mathbf{R_f}$ and profit. However, this may be true only within certain distance ranges, since as distance increases, high-speed operational cost increases substantially to a point where cargo rates would have to be extremely high--perhaps approaching airfreight rates-- in order to cover the high operational cost and make enough profit to compensate investors and operators. In addition, as distance increases, so, too, does trip time, thereby reducing round-trip frequency and gradually losing the advantage of fast vessels over the alternative airfreight in terms of time and cost.

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