Opportunities for increased profit and reduced cost and emissions by service differentiation within container liner shipping

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ABSTRACT

This paper investigates opportunities for increased profit and reduced emissions and cost by service differentiation within container shipping. Traditionally the strategy among the container lines has been profit maximization by utilizing economies of scale through the building of larger and faster vessels. In 2008, the financial crisis in combination with higher fuel prices put an end to this progress and in today's market operators are basically trying to survive by providing standardized services at the lowest possible cost. This study investigates alternative strategies and the results indicate that container lines should provide two different services instead of one standardized service. A fast service to be more competitive versus air freight for fast-moving goods and a slow service to be more competitive versus traditional shipping types for transport of minor bulk, break bulk, liquid bulk and project cargo.

Key words: Greenhouse gas emissions; Comparative analysis; Competitive strategies; Air versus Sea transport; Shipping and environment

1. **Introduction**

The main motivation for this study is twofold: first to investigate the opportunities for increased profit by service differentiation within the container liner industry, second to determine whether service differentiation can contribute to reducing total cost and emissions from sea and airfreight. Presently, more than 80% of international trade measured in tons (all tons are metric) is performed by seagoing vessels, of which container vessels transport 15% to 20% measured in weight and considerably more measured in value. While the total tonnage transported by air freight is small in comparison with ocean-going tonnages, the value of the transported goods adds up to a significant proportion of world trade. Comparing greenhouse gas emissions (GHG), marine transport accounts for 3.3% of CO_2 global anthropogenic emissions according to the *Second IMO GHG study* (Buhaug et al., 2009) while aviation accounts for 2.1% according to the *World Air Transport Statistics* (2011).

Containerization basically consists in packaging cargo in large standardized containers for efficient shipping and handling, instead of managing this cargo as smaller units through the transport chain. Containers have long been used for medium- and high-value products, but today, also typical bulk and break bulk products like grain, paper, pulp and steel products are transported in containers (Lindstad, Asbjørnslett, and Strømman, 2011).

Cullinane and Khanna (2000) and Notteboom and Vernimmen (2009) have studied the business models of container lines. Their findings indicate that a typical strategy has been profit maximization by utilizing economies of scale through the building of larger vessels to reduce transport cost. Compared to conventional shipping the advantages are: parcel sizes down to one container; low cost by employment of large vessels; and short transport time due to high speeds. Compared to air freight the advantages are: lower cost and with high speeds the time difference between air and sea becomes small, which reduces customer willingness to pay the additional cost for airfreight. In 2008, the financial crisis and lower trade growth in combination with higher fuel prices put an end to this strategy and in today's market operators are basically trying to survive through providing standardized services at the lowest possible cost. This low-cost strategy basically means that container lines have reduced speeds from the level of 22 – 28 knots, seen prior to 2008, to today’s level of 12 – 20 knots according to Waals (2013). The background for these speed reductions is that the power output required for propulsion is a function of the speed to the power of three to four according to Kristensen (2010), which simply implies that when a ship reduces its speed, the fuel consumption per freight work unit is reduced. The high end of the current speed interval is used on front-haul legs, for instance from Asia to Europe or to North America according to Waals (2013), and the low end, i.e., 12 knots, is used on the backhaul (return leg to Asia). This strategy leads to longer transport times for fast-moving goods versus airfreight compared to prior to 2008.

According to Porter (1980), the essence of formulating a competitive strategy is to relate a company to its environment. Although the relevant environment is very broad, encompassing social as well as economic forces, the key aspect of the firm’s environment is the industry or industries in which it competes. For container shipping, the main competition context is long-distance freight transport either within a region or intercontinentally. Forces outside the container shipping industry are significant, since container lines meet competition from air freight for fast-moving goods and from other shipping segments when they want to transport minor bulk, break bulk, liquid food products and chemicals in containers instead of in conventional tonnage. Typical examples of cargo types for which container vessels compete with air freight include electronics, fashion products, sports gear, spare parts, tools, machines, expensive cars, and perishable goods (Lindstad, 2013). Between the pure air transport or sea transport options, we find what is termed “Air & Sea”, where goods are transported first by sea and then by air or vice versa. A typical example of Air & Sea transport involves sea transport from Asia to the Middle East followed by air transport to Europe. By combining these modes, the user gets freight that is faster than by sea transport alone but cheaper than by air freight only. In the shipping market, transport of fertilizer is one example that illustrates the continuous competition between container vessels and conventional tonnage. Fertilizer products can be transported as bulk with standard bulk carriers, in big bags in open hatch vessels, as bulk in containers or bagged on pallets stuffed in a container. Chemicals represent another example of products that can either be transported in dedicated tanks on a chemical vessel or in chemical tank containers on a container vessel. When it comes to large quantities, container vessels can hardly compete, however for logistics solutions serving supply chains in a door-to-door perspective, the parcel sizes are smaller, which makes the container vessels more competitive.

Porter (1980) states that there are three potentially successful generic strategic approaches to outperforming other firms in an industry: i) overall cost leadership – lowest cost position, ii) differentiation – creating something that is perceived across the industry as unique, design/brand image/service, and iii) focus – to focus on a specific segment or geographic market. When relating these strategies to the existing behaviour of the container lines, it appears that all of them are trying to survive through providing standardized services at a lowest possible cost. However, none of them have managed to achieve an overall cost leadership. An explanation may be the high degree of competition, due to a large number of container shipping lines with access to the best technologies, i.e., vessel types, engines and container handling equipment technologies. A differentiation strategy basically means to perform something differently compared with how it has commonly been carried out and how the competitors are doing it. In a narrow definition, competitors could potentially signify only other container lines, while in this study; competitors also include air freight and conventional shipping companies.

This study compares the current cost-minimizing standardized service provided by the container lines with what is achievable through a differentiation strategy as described by Porter (1980). For this purpose, a model has been developed to calculate emissions and costs for sea freight and air freight as a function of: their characteristics; the transported cargo and the capacity utilization. The employed model is described in section 2, its application and the data are presented in section 3, and the obtained results are discussed in the final section.

2. Description of the model

The main objective of our model is to calculate emissions and costs for sea freight and air freight as a function of their characteristics and the transported cargo. Not only does this enable comparisons of container vessels and other sea-going vessels operating at various speeds, it also enables comparisons of container vessels with air freighters based on typical utilization figures for the compared cargo carriers as described in section 3.1. Furthermore, it renders possible comparisons of existing cost-minimizing strategies of container lines with alternative strategies. The model comprises four main equations.

The annual operational profile of a cargo carrier (ocean-going vessels or air freighters) comprises days or hours on cargo voyages, days or hours on repositioning voyages and idle days or hours as expressed by equation 1:

$$T = \sum_{i=1}^{N_c} \left(\frac{D_i^c}{v} + T_i^{l\&d} + T_i^w \right) + \sum_{i=1}^{N_b} \left(\frac{D_i^b}{v} + T_i^w \right) \quad (1)$$

Here, the first term on the right-hand side of the equation gives the annual number of days used on cargo voyages, and D_i^c is distance per voyage, v the speed per voyage, $T_i^{l\&d}$ the time used for loading and discharging cargo per voyage, T_i^w the waiting time and N_c the annual number of cargo voyages. The second term gives the annual number of days used on repositioning voyages, where D_i^b is the distance per voyage, v is the speed, $T_i^w$is the waiting time and N_b is the annual number of repositioning voyages.

The annual fuel consumption *F* comprises the fuel used on cargo voyages F_c and that used on repositioning voyages F_b, and is given by equation (2):

$$F = F_c + F_b = \sum_{i=1}^{N_c} \left(K_f \cdot \left(\frac{P_i^{Mt \cdot v} \cdot D_i^c}{v} \right) + F_i^{l\&d} + F_i^w \right)$$

$$+ \sum_{i=1}^{N_b} \left(K_f \cdot \left(\frac{P_i^{Mt \cdot v} \cdot D_i^b}{v} \right) + F_i^w \right) \quad (2)$$

Here, the first term gives the annual fuel consumption for cargo-carrying voyages and the second term provides the annual fuel consumption for the repositioning voyages, $\boldsymbol{N_c}$ represents the number of cargo voyages, $\boldsymbol{N_b}$ the number of ballast voyages, $\boldsymbol{K_f}$ the amount of fuel in grams per produced kWh, $\boldsymbol{P_{M_t \cdot v}}$ the power required as a function of speed $\boldsymbol{v}$ and the total cargo carried $\boldsymbol{M_t}$, including the fuel required, the empty weight of cargo containment units on board the cargo carrier and any other additional weight such as ballast water. D is the distance, $\boldsymbol{F_{l\&d}}$ is the fuel used during loading and discharging and $\boldsymbol{F_w}$ is the fuel consumption while waiting.

The annual amount of CO_2 emitted per ton kilometer (ton km) or cubic meter kilometer (m^3km) ε by the cargo carrier is calculated using equation 3:

$$\varepsilon = \frac{F}{\sum_{i=1}^{N_c}(D_i^c \cdot M_i)} \cdot K_e \quad (3)$$

where F is the annual fuel usage in tons, N_c is the number of cargo voyages, K_e is the emitted CO_2 per unit of fuel burnt, D_i^c is the distance per cargo voyage, M_i is the amount of paying cargo transported on a voyage which excludes the fuel used, cargo containment units and any ballast water.

The cost per cubic meter kilometer (m^3km) or ton kilometer (ton km), comprises the cost of fuel, the daily financial and operational costs of the cargo carrier, airport or port fees, airspace or fairway fees and cargo handling, as expressed by equation (4):

$$\mathrm{C}_{D \cdot M} = \frac{1}{\sum_{i=1}^{N_c} D_i^c \cdot M_i} \cdot \left((F \cdot C_{Fuel}) + TC \cdot T + \sum_{i=1}^{N_c} C_i^{hpf} + \sum_{i=1}^{N_b} C_i^{pf} \right) \quad (4)$$

The first factor, transforms the cost from an annual cost to a cost per freight unit distance. Inside the main bracket, the cost of fuel is calculated by multiplying the annual quantity of burned fuel F (as determined by equation (2)) by the cost of fuel C_{Fuel}. TC is the daily operational and financial costs of the cargo carrier and T corresponds to the number of days per year or total days if the cargo carrier has been in service for less than a year. The two last terms summarize handling, port and voyage fees C_i^{hpf} for the cargo voyages and the port and voyage fees C_i^{pf} for the repositioning voyages.

To sum up, we can by combining equations 1, 2, and 3 describe the greenhouse gas emissions associated with a specific operational mode, while equations 1, 2 and 4 provide the costs.

3. Application and analysis

The primary objective of this analysis is to compare the current cost-minimizing standardized services provided by the container lines with what is achievable through a differentiation strategy. This implies that alternative cost minimizing scenarios will be compared against alternative differentiation scenarios to identify the most promising strategy.

3.1. Empirical basis

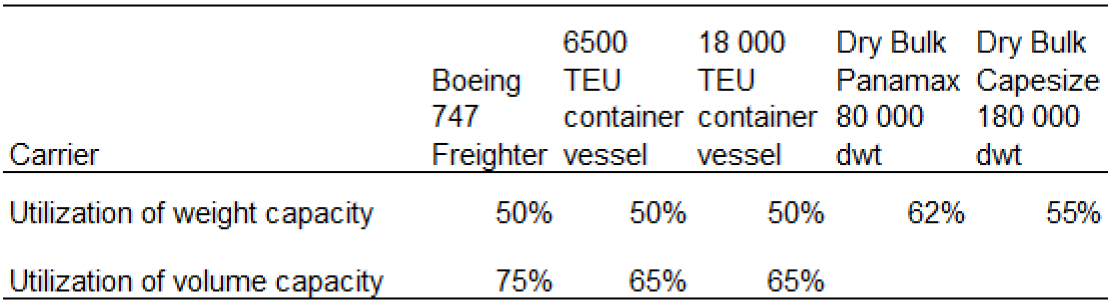
The data sets used for airfreight are based on the *World Air Transport Statistics* (2011) and Air freight trade data by Kupfer et al. (2011). Cost, utilization and other operational figures are based on CargoLux (2011), which is a fully specialized air freight company. The technical specification for the Boeing 747 freighters and the cost for new air freighters based on list prices published by Boeing (2012) adjusted for standard rebates as described by Hegnar (2012). The data set for sea transport is based on the vessel database and movement data published by IHS Solutions (www.ihs.com1) and the Second IMO GHG study (Buhaug et al. 2009). Cost, utilization and other operational figures are based on

Lindstad, Asbjørnslett, Strømman (2012) and Lindstad (2013). In 2010, the world's airlines transported 2.3 billion passengers, who flew an average of 2000 km per trip, as well as freight at an amount of 180 billion ton km. Half of this freight was transported in the belly of passenger planes and the other half by pure freight aircraft. Since half of all air freight goes by pure freighters, we follow that path by calculating emissions for a pure air freight operation. Within this segment, we find major companies like DHL and FedEx, but since these corporations operate in all transport modes, we decided to use CargoLux as the benchmark. In 2010, CargoLux operated a fleet of 14 standardized Boeing 747 freighters. Light cargo weights tend to be favoured by operators, since the fuel consumption per unit distance is a function of the take-off weight, where a 5% reduction in take-off weight gives a 5% reduction in fuel consumption for the whole voyage according to Anderson (2012). This is also illustrated by the fact that the newest version of the Boeing 747-freighter, the 747-8F, which has a capacity of 857 m^3, can carry a maximum cargo load of 115 tons with a flying distance of 10 000 km. This equals an average weight per cubic meter of 135 kg (0.135 in density per volume unit) when both the volume and the weight capacity are fully utilized. If the non-stop flying distance is raised to 14 000 km, the maximum cargo load drops to 75 tons, since the plane has to carry more fuel when the flight distance is increased and the cargo capacity is correspondingly reduced. The volume capacity can still be fully utilized if the average cargo weight per cubic meter drops to 90 kg or less. And if the flight distance is reduced to 8 000 km or less the weight of cargo can be raised to 134 tons.

While aircraft operate at speeds of 800 - 850 kilometer per hour (km/h), vessel speeds depend on vessel type and size. Typical carriers of wet and dry bulk products operate at speeds of around 18 - 28 km/h (10 – 15 knots) while the fastest container vessels have service speeds of up to 50 km/h (25 – 27 knots). The average size of bulk, tank and container vessels has increased year after year. Recently (in 2013), Maersk Line have introduced a container vessel with a capacity of 18 000 TEU and a deadweight of more than 200 000 tons (Maersk, 2013). Apart from the increase in size, the main differences compared with current vessels are that its maximum speed is slightly lower, and that it is optimized to sail most of its voyages at slower speeds. Within the bulk segment, the largest vessels built today carry nearly 400 000 tons, whereas a decade ago the largest carried 200 000 tons and twenty years ago very few vessels carried more than 100 000 tons. The largest of these bulkers are used purely in iron ore and coal trades and are hence of no relevance for this study. Comparing operational pattern, bulk vessels are employed in tramp trades which implies that there will be a mix of cargo voyages, i.e. fully loaded and repositioning voyages being completely empty (ballast). Container vessels are employed in liner trades which imply that they generally neither will be fully loaded nor completely empty. Lindstad, Asbjørnslett and Strømman (2012) have studied operational patterns for the world fleet as a function of vessel type and size groups. Their findings indicates that Panamax vessels in average will sail 8 cargo voyages and 5 ballast voyages per year, Capesize vessels will in average sail 6 cargo voyages and 5 in ballast, large container vessels will in average sail 11 cargo voyages per year. Translated to capacity utilization this implies 62 % average weight utilization of the Panamax, 55 % average weight utilization of the Cape-size, 50% weight utilization and 65% volume utilization of the container vessels. It should here be noted that these weight utilization figures are based on the pure cargo weight which implies that the empty weight of the containers comes in addition.

This study examines four different shipping alternatives: two container vessel sizes and two bulk vessel sizes. 1) The current average deep-sea container vessel, represented by a 6 500-TEU 80 000-dwt. vessel which is generally built for a service speed of 46 km/h (25 knots). 2) An 18 000-TEU vessel built according to Maersk's specification and designed to operate in the speed range of 20 – 42 km/h (11 – 23 knots). 3) A 80 000-dwt Panamax bulk vessel built for a maximum speed of 27 km/h (14 knots). 4) A 180 000-dwt Capesize bulker built for a maximum speed of 28 km/h (15 knots). The latter, which is the largest of the two bulk vessels, is included purely to show economies of scale effects within bulk shipping since it is not a real option for any trades where bulk and containers vessels compete. Table 1 displays the average utilization figures for weight and volume for the cargo carriers investigated in this study.

Table 1: Average utilization figures based on operational data



Carrier	Boeing 747 Freighter	6500 TEU container vessel	18 000 TEU container vessel	Dry Bulk Panamax 80 000 dwt	Dry Bulk Capesize 180 000 dwt
Utilization of weight capacity	50%	50%	50%	62%	55%
Utilization of volume capacity	75%	65%	65%		

When comparing air and sea, the sea route distance between origin and destination will in general be longer than the air route, and the difference in transport distance is therefore an important exogenous variable when comparing alternative strategies. To give some examples: Shanghai – Seattle is 9200 km by air and 9400 km by sea, while Shanghai – New York is 11 900 km by air and 19600 km by sea, Shanghai- Amsterdam is 8900 km by air and 19 600 km by sea, Tokyo – Amsterdam is 9300 km by air and 21 000 km by sea, Tokyo – St. Petersburg is 7600 km by air and 23 000 km by sea, Dubai – Amsterdam is 5200 km by air and 11 400 km by sea. As these examples show, the ratios of air and sea distances for typical trades range from as little as 1:1 directly across the Pacific to as much as 1:3 for trades from North-East Asia to North-West Europe. The average ratio is not far from 1:2. Consequently, this study compares air and sea freight based on a distance ratio of 1:2 where 10 000 km is used as a typical air distance and 20 000 km (11 200 nm) as the sea distance. It could be argued that these distances are above the average both for sea and air; however they represent typical distances for Asia – Europe and Asia – East Coast North America trades.

3.2 Cost calculations

The developed model have been used to calculate cost and emissions for air freight and the alternative sea-going vessel concepts, thus enabling comparisons of the existing cost-minimizing strategies with alternative strategies in the scenario section. Table 2 contains both the input for and the results of the calculations for the air freighter and the 4 vessel concepts. The first section (1) contains the basic cost and capacity inputs for all the carriers, where the capacities reflect the net payload capacities after deduction of cargo containment units, fuel and supplies. The second section (2) contains average operational volume and weight utilization for these carriers as shown in Table 1. The third section (3) contains voyage speeds and the resulting voyage time for Asia – Europe return trips. Here, the speed for the air freighter is fixed at 850 km/h, four speeds are used for the container vessels (56, 46, 39, and 22 km/h), and two speeds are employed for the dry bulkers (22km/h and 18 km/h). It should be noted that very few container vessels can attain 56 km/h (30 knots) based on their installed power and that the 18 000-TEU designs by Maersk have a top speed slightly below 46 km/h (25 knots). However, to enable an assessment of the consequences of higher speeds, the additional power required for 56 km/h for both designs and 46km/h for the 18000-TEU designs have been calculated. The fourth section (4) contains fuel consumption as a function of cargo carrier and the chosen speed. This is followed by CO_2 emissions per ton and cubic meter per km transported and for the whole one-way voyage. The fifth section (5) contains average cost per ton and cubic meter as well as cost per TEU and marginal cost per ton for the container carriers.

Table 2: Cost figures as a function of freight carrier and voyage speed

	Carrier		Boeing 747 Freighter	6500 TEU container vessel				18 000 TEU container vessel				Dry Bulk Panamax 80 000 dwt		Dry Bulk Capesize 180 000 dwt	
1	New built price 2012	MUSD	180	80				190				30		50	
	Annual deprication and financial cost	MUSD	14.4	6.4				15.2				2.4		4.0	
	Annual operational cost	MUSD	18.0	3.2				7.6				1.2		2.0	
	Daily TC-equivalent	USD	93 000	27 000				65 000				10 000		17 000	
	Cargo - weight capacity	ton	115	63 000				160 000				76 000		170 000	
	Cargo - volume capacity	m^3	857	162 500				450 000							
2	Utilization of weight capacity	%	50%	50%				50%				62%		55%	
	Utilization of volume or TEU capacity	%	75%	65%				65%							
	Average volume payload	m^3	640	106 000				293 000							
	Average TEU payload	TEU		4 200				11 700							
	Average weight payload	ton	57.5	32 000				80 000				47 000		93 000	
	Distance Asia - Europe	km/h	10 000	20 000				20 000				20 000		20 000	
3	Voyage speed	km/h	850	56	46	39	22	56	46	39	22	22	18	22	18
	Voyage speed	knots		30	25	21	12	30	25	21	12	12	10	12	10
	Voyage time Asia - Europe t/r including loading and discharging	days	1.5	44	49	56	89	51	57	65	96	86	104	90	109
4	Fuel consumption Asia - Europe t/r	ton	200	15 200	9 700	7 300	4 000	29 500	16 800	13 300	7 300	2 100	1 500	3 200	2 500
	CO_2 Emissions per ton km	gram per ton km	550	38	24	18	10	29	17	13	7	4	3	3	2
	CO_2 Emissions per cubic km	gram per m^3 km	50	11	7	5	3	8	5	4	2				
	CO_2 Emissions per ton transported	ton/ton	5.51	0.75	0.48	0.36	0.20	0.58	0.33	0.26	0.14	0.07	0.05	0.05	0.04
	CO_2 Emissions per cubic transported	ton/m^3	0.50	0.23	0.15	0.11	0.06	0.16	0.09	0.07	0.04				
5	TC & Fuel cost Asia - Europe t/r	MUSD	0.33	10.8	7.4	6.1	4.9	21.9	14.3	12.6	10.8	2.2	2.0	3.5	3.4
	Average cost per cubic meter	USD/m^3	257	51	35	29	23	37	24	21	18				
	Average cost per ton	USD/ton	2865	168	116	96	77	137	89	79	68	23	21	19	18
	Average cost per TEU	USD/TEU		1280	886	729	585	936	610	538	463				
	Marginal cost per ton with 25 ton per 20 feet container	USD/ton		51	35	29	23	37	24	22	19				

Main observations include the fact that it might be interesting to compare unit emissions per km within one transport mode, especially when all transport modes have similar distances. However, in most cases where air and sea are compared, it is more relevant to compare emissions per ton transported for the whole voyage. When comparing emissions per transported ton on one transport leg, the ratio between sea and air is 1:8 between the aircraft and the 6 500-TEU vessel at 56 km/h, 1:11 between the aircraft and the 6 500-TEU vessel at 46 km/h, 1:16 between the aircraft and the 18 000-TEU vessel at 39 km/h, 1:40 between the aircraft and the 18 000-TEU vessel at 22 km/h, 1:80 between the aircraft and the Panamax bulker at 22km/h.

If these emissions are compared per cubic meter transported, the ratio is 1:2.5 between the aircraft and the 6 500-TEU vessel at 56 km/h, 1:4 between the aircraft and the 6500-TEU vessel at 46 km/h, 1:6 between the aircraft and the 18 000-TEU vessel at 39 km/h and 1:12 between the aircraft and the 18 000 TEU container vessel if it travels at 22 km/h. Regarding cost, the difference between air and sea per cubic meter is less than expected, and since these figures only include the main carriage, the real difference in percentage terms is smaller since terminal handling and hinterland transport might be a at a similar level for all the cargo carriers. When comparing the cost per transported ton for container and bulk vessels, the following observations can be made. Based on average values, the container vessels are not competitive since the average cost even for the 18 000-TEU vessels sailing at 12 knots is 68 USD per ton compared to 23 USD per ton for a Panamax sailing at the same speed. However, in the container business, where the focus is more on revenue and cost per TEU, the average container weight tends to be less than the design weight, and heavy-weight containers will thus substitute ballast water instead of paying cargo. With a pricing model where the customer pays per TEU, the marginal cost for transporting heavy products like fertilizer, pulp and timber with container vessels sailing at low speeds such as 22 km/h is similar to the cost of transporting them with a Panamax Dry bulker, i.e. 23 USD per ton.

3.3 Decision criteria for selecting air versus sea transport

Simply put the choice between air freight, sea freight or combining the two boils down to cost and profit assessments. This means that high-value products generally go as air freight since the financial cost of carrying excess stock due to longer transport times is larger than the additional transport cost. On the other hand, it never pays to use air freight for low-value goods, even with very long transport times, except if these goods are needed to manufacture the main product or in an emergency. Product shelf life is another reason for using air freight, not only for perishable goods such as fresh fish, seafood and strawberries, but also for new electronic products and new sports gear where a price premium can be obtained by bringing products faster to market. In other cases, the decision to use airfreight is taken to avoid a loss in revenue due to potential stock-outs. This means that when the decision-makers decide to use air instead of sea transport, the cost savings from less stock in transit and transport, or lost contribution due to delayed or lost sales has to be more than 200 – 250 USD per m^3 to compensate for the cost differences between air and sea as calculated in Table 2. Figure 1 gives an illustration of the relationship between the various decision criteria when choosing between air and sea freight.

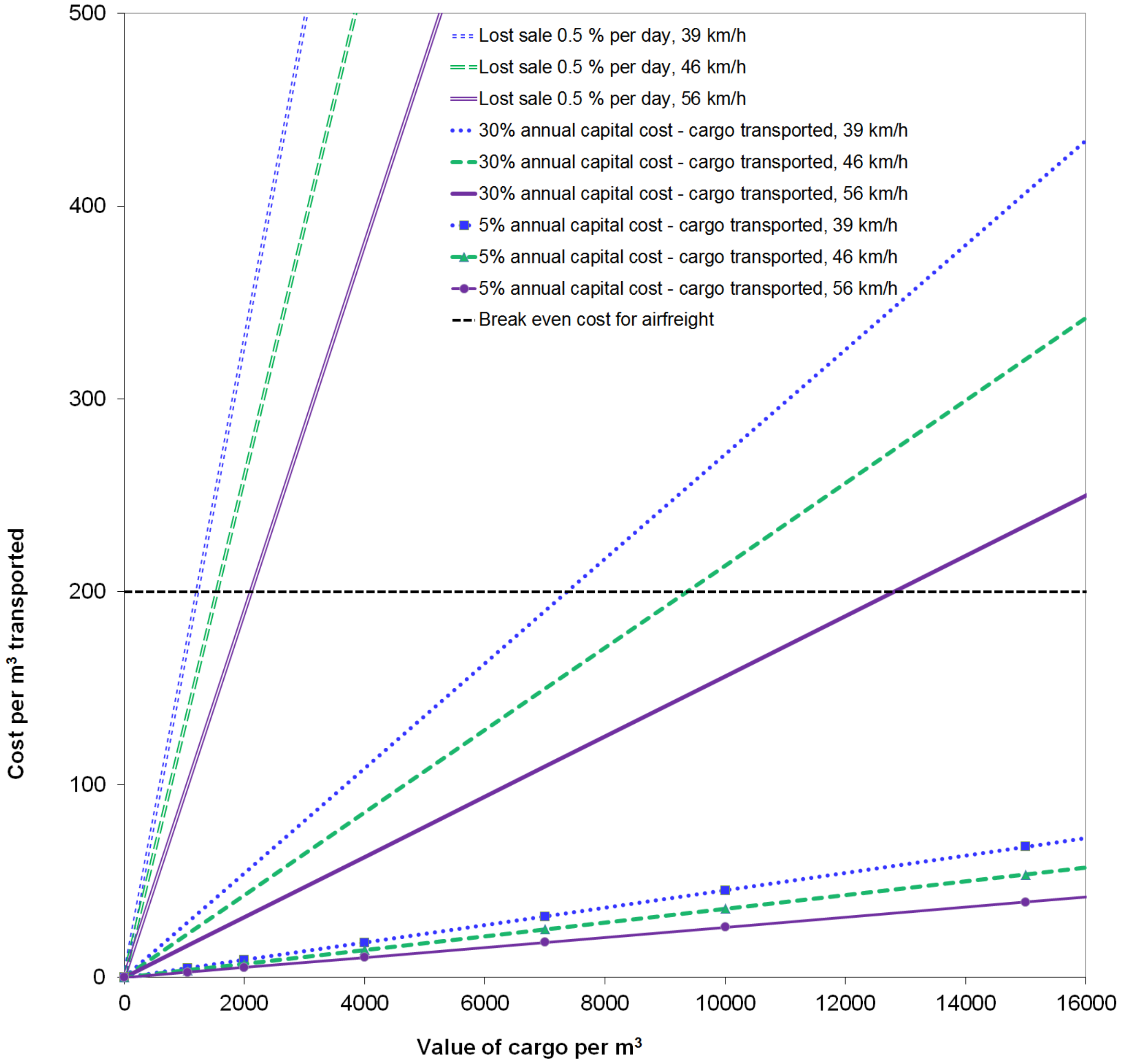


Figure 1: Illustration of decision criteria when choosing between air or sea freight

The main observations from Figure 1 are that: If the assessment is made on the basis of lost sales due to stock outs, air freight becomes competitive for cargo values as low as 1 000 – 1 500 USD per m^3. If the assessment is done on the basis of cost for small and medium-sized companies, might have to pay interest rates as high as 30 %, air freight becomes competitive when cargo values exceed 8000 USD per m^3 for the 18 000-TEU vessel at a speed of 39 km/h, 10 000 USD per m^3 for the 6500-TEU vessel at a speed of 46 km/h and 14 000 USD per m^3 for the 6500-TEU vessel at a speed of 56 km/h. Major multinational companies have lower financial costs and generally less uncertainties, and today within some sectors, interest rates might be as low as 5% on the capital for the most solid businesses. With 5 % interest rates, air freight becomes competitive when cargo values exceed 50 000 USD per ton for the 18 000-TEU vessel at a speed of 39 km/h and considerably higher values for the faster services. Figure 1 also tells us that the fast service has a cut-off point against air freight at higher product values than the slow service, which signifies that slowing down all container vessels will contribute to a higher market share for air freight, and *vice versa*.

3.4 Scenarios

Six scenarios, i.e., scenario 2 – 7, have been investigated and compared with the basic scenario 1, which reflects speeds and market behaviour prior to the financial crisis in 2008. In this quantitative assessment, we compare as if the average global air and container tonnages are transported 10 000 km by an air freighter or 20 000 km by an ocean-going container vessel. This is a simplification since both the size of the carriers and the distances will vary, however it gives a good benchmark for comparing the scenarios.

Table 3 contains both the input to the quantitative assessment for the scenarios and the results. The investigated scenarios are: 1 – Basic case from before 2008, 2 – Reduced speeds of 6500-TEU vessels from 46 to 39 km/h (25 to 21 knots). 3 – Replacement of the 6 500-TEU vessels with the 18 000-TEU ones and speed maintained at 39 km/h, 4 – Same as 3, but with an increased air freight market share due to increased voyage times caused by the speed reduction from 46 to 39 km/h and longer loading and discharging times with the largest vessels, 5 – Differentiation of container speeds where the 6500-TEU vessels operate at 46 km/h, transport 20% of the containers and have an average value of 1000 USD per m^3 and above based on average freight values as published by Leachman (2008) and where the 18 000-TEU vessel carry the remaining 80% of the container cargo at a speed of 22 km/h, 6 – Differentiation in combination with increased speeds where the 6500-TEU vessels operate at 56 km/h, transport 20% of the containers and have an average value of 1000 USD per m^3 and above, and where the 18 000-TEU vessel carry the remaining 80% of the container cargo at a speed of 22 km/h, , 7 – Same as 6 apart from the fact that the air freight market share is reduced to the speed increase of the fastest container vessels.

Table 3: Quantitative assessment of scenarios with focus on cost and emissions

Carrier	Speed in km /h	Carriers	Freight Work in billion ton km	Total tonnage in million tons	Cost per ton	CO_2 emissions in kg per kg transported	Cost in Million USD	Total cost in million USD	Cost reduction compared to base case	CO_2 emissions in million tons	Total CO_2 emissions in million tons	CO_2 reduction compared to Base case
1 - Base case Before 2008												
Airfreight	800	747-Freighter	180	18	2 865	5.51	52 000			99		
Container	46	6 500 TEU	13 844	692	116	0.48	80 000	132 000		333	432	
2 - 6500 TEU vessels operating at 39 km/h												
Airfreight	800	747-Freighter	180	18	2 865	5.51	52 000			99		
Container	39	6500 TEU	13 844	692	96	0.36	66 000	118 000	11%	249	348	19%
3 - 18 000 TEU vessels operating at 39 km/h												
Airfreight	800	747-Freighter	180	18	2 865	5.51	52 000			99		
Container	39	18 000 TEU	13 844	692	79	0.26	55 000	107 000	19%	180	279	35%
4 - 18 000 TEU vessels operating at 39 km/h and 10 % increased airfreight												
Airfreight	800	747-Freighter	198	20	2 865	5.51	57 000			109		
Container	39	6500 TEU	13 826	691	79	0.26	55 000	112 000	15%	180	289	33%
5 - Differentiated container speeds												
Airfreight	800	747-Freighter	180	18	2 865	5.51	52 000			99		
Container	46	6500 TEU	3 461	173	116	0.48	20 000			83		
Container	20	18 000 TEU	10 383	519	68	0.14	35 000	107 000	19%	73	255	41%
6 - Higher container speeds												
Airfreight	800	747-Freighter	180	18	2 865	5.51	52 000			99		
Container	56	6500 TEU	3 461	173	168	0.75	29 000			130		
Container	20	18 000 TEU	10 383	519	68	0.14	35 000	116 000	12%	73	302	30%
7 - Higher container speeds and 10 % reduced airfreight												
Airfreight	800	747-Freighter	162	16	2 865	5.51	46 000			89		
Container	56	6500 TEU	3 479	174	168	0.75	29 000			130		
Container	20	18 000 TEU	10 383	519	68	0.14	35 000	110 000	17%	73	292	32%

Main observations include that all the investigated scenarios lead to reduced costs and emissions compared with the basic case. Among the various scenarios, scenario 5 (with differentiated container speeds where the 6500-TEU vessels operate at 46 km/h and the 18 000-TEU vessels operate at 22 km/h) provides the combination of the lowest cost and emissions. In terms of cost, the difference between this scenario and scenario 3 (where the 18 000-TEU vessels operate at 39 km/h) is zero, but with regard to emission, the difference is more than 10 %. In addition, it is not unreasonable to argue that the increased transport time caused by longer turnaround times due to longer loading and discharging times for the 18 000-TEU vessels as well as sailing speeds reduced from 46 km/h to 39 km/h should lead to increased air freight which might make scenario 4 more plausible than scenario 3. Consequently, scenario 5 (with the differentiated speeds) becomes even better compared with the single speed schemes. Another observation is that increasing the speed of the fastest container vessels from 46 km/h to 56 km/h results in higher cost and emissions even if such a speed increase contributes to reduced air freight volumes, as in scenario 7.

In a qualitative assessment, the main difference between scenario 3 or 4 and scenario 5 is that scenario 5 will enable container lines to favour the best paying cargo and give fast tracks, which is exactly in line with the differentiation strategy as described by Porter (1980). It also reduces the average transport cost and the marginal freight cost required when container lines compete with conventional tonnage for commodities like minor bulk, break bulk and chemicals. When comparing scenario 3 or 4 with 5, all scenarios give cost benefits. However, scenario 5 provides better opportunities for a higher market share of goods in the market where container vessels compete with traditional bulkers, as well as opportunities for charging the 20 % of the cargo on the fast container vessel with a price premium. Higher rates, larger volumes and a lower cost increase profit and hence make differentiated speeds more profitable than the benefits that are achievable by employing larger vessels in a single speed scheme.

4. Discussion and conclusions

The main motivation for this study has been to investigate the opportunities for increased profit by service differentiation within the container liner industry and to determine whether service differentiation can contribute to reducing total cost and emissions from sea and airfreight. The results indicate that container lines should provide two different services instead of one standardized service as they do today. A fast service to be more competitive versus air freight for fast-moving goods and a slow service to be more competitive versus traditional shipping types for the transport of minor bulk, break bulk, liquid bulk and project cargo. In terms of cost, the difference between operating a two speed scheme and a one speed scheme which fully utilizes economies of scale is small, but with regard to emissions, the reduction with a two speed scheme is more than 10 %. In addition, longer loading and discharging times with large vessels in combination with reduced sailing speed could lead to increased air freight and hence make the two speed scheme even more competitive regarding cost and emissions. Regarding profit, the main difference between operating a one and a two speed scheme is that a two speed scheme will enable container lines to favour the best paying cargo even at the terminals compared to the other cargo. A two speed scheme will also reduce the cost for the slow speed service compared to a one speed service. This will make it even more competitive versus conventional tonnage when they compete for commodities like minor bulk, break bulk and chemicals.

The introduction of a two speed scheme will be a major challenge for any container line, which could certainly be seen as an argument for not trying at all. However according to Porter (1980), strategies that can be implemented by all market players provide low profit while approaches that can only be followed by one or a few are much more profitable. This means that the first container lines with the required resources and courage to go for a two-speed scheme will be in a unique position to capture market shares and increase profitability.

When comparing our results with current policies discussed by IMO, ICAO and UNFCCC, the focus has so far been on exploring emission reduction options for sea and air transport separately, neglecting the fact that they partly compete for the same freight cargos and passengers. Neither IMO nor ICAO has addressed possible evasion effects of the measures debated or the fact that reductions within one sector can lead to increases within another.

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