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# Low Carbon Shipping Conference 2012

## New panamax and its implications for ship design and efficiency

*Paul W Stott*<sup>1</sup>

<sup>1</sup> School of Marine Science & Technology, Newcastle University, Newcastle, UK  
Email: paul.stott@ncl.ac.uk

### Abstract

The expansion of the Panama Canal presents an opportunity for increased transport efficiency and reduced emissions. Shipping is famously a ‘derived’ demand and the evaluation of this opportunity would logically be predicated on trade analysis to review how the expansion may affect cargo flows and the consequent effect this would have on the fleet. The incidence of panamax beam in the fleet is much greater than is required to service Canal trades, however, and the benefits are likely to be greater than would be estimated through a trade-based analysis. The likely consequences of the relaxation of the constraint on ship design in the three main cargo carrying sectors (wet and dry bulk and container) are reviewed with comments on the potential for reduction in emissions stemming from this change.

*Keywords:* Ship design efficiency Panama Canal panamax

### 1. Introduction

The expansion of the Panama Canal, opening the short-cut route between Atlantic and Pacific to larger vessels, will, arguably, be the most significant development in ship routing in the 100 years since the Canal first opened. The aim of this paper is to consider what effect this event may have on ship design and shipping transport efficiency.

Demand for shipping is famously a ‘derived’ demand (Stopford, 2009), that is to say that the demand is not for the ship itself but for the transport service that the ship provides, from which the demand for the ship is derived. It would be logical therefore to approach the analysis of the effect on ship design that may stem from this change through analysis of the change in transport demand that the expansion might afford. This would be difficult, however, because the consideration of this problem in advance of the Canal opening has proven intractable. An overview of the possible development of trade patterns (Rodrigue and Notteboom, 2012) concluded that “*the expanded Panama Canal will not face a ‘business as usual’ situation, but the new rules of the global trade game are not clear*”. The number of uncertainties is too large to predict the change in trading patterns with any certainty. Fortunately, however, the implications of the expansion with reference to ship design can be reviewed independently of the likely change in trading patterns. The reason for this is that the use of the Panamax beam constraint in ship design is not directly related to an intention to route through the Canal. In 2010, 204.8 million long tons of cargo passed through the Canal (Panama Canal Authority (PCA), 2011), equivalent to around 208 million metric tonnes. This is less than 2.5% of the total volume of world trade of around 8.4 billion tonnes recorded by UNCTAD in that year. Despite this, however, around 25% of the deep sea commercial shipping fleet (defined here as ships over 5,000 GT) has Panamax beam – around 8,500 ships in total. The reason for this is that vessels are likely to adopt Panamax beam for reasons of flexibility. Reduced flexibility in the eyes of ship owners is equivalent to increased business risk and this would be reflected in the re-sale value of the ship. The fleet has therefore been considerably constrained in case it has to use the Canal, not necessarily because in reality it does use the Canal.

The implications of the expansion of the Canal on ship design are therefore far wider than would be suggested by the analysis of trade alone. This is not to say that the analysis of trading patterns per se

is not an important input to the question about the shape of the post-expansion fleet. In particular, just because the Canal would enable a larger vessel to transit this does not mean to say that ship owners will necessarily want a larger vessel. A demand for larger ships would only be derived from a demand for larger parcel sizes (Stopford, 2009) and the analysis of this subject has formed part of the following research.

The change in ship dimensions that the Canal will accommodate is summarised in Table 1:

	Length (m)	Beam (m)	Draft (m)	Air Draft (m)
Old Panamax	289.6	32.31	12.04	57.91
New Panamax	366.0	49.0	15.2	57.91

**Table 1: Summary of old and new panamax dimensions (Panama Canal Authority (PCA), 2010)**

As will be demonstrated by the analysis presented below, for container ships the limit on ship size will move from being beam-constrained to being length-constrained. For bulk ships, on the other hand, the Canal will shift from being beam-constrained to being draft-constrained. As with the Suez Canal, therefore, which is also draft-constrained, the draft limit will present restrictions on fully laden bulk ships but the length and beam limits will permit larger vessels to transit in light or partially laden conditions. This adds a further dimension to the ship-routing conundrum, enabling larger vessels to transit the Canal in ballast, opening up the shortened route for at least part of the operating cycle of larger ships.

The effects of the expansion of the Panama Canal on shipping's emissions are therefore complex. Constituent considerations include:

1. Larger vessels (with maximum size depending on whether the vessel is laden or in ballast) will be able to take advantage of the short-cut route between Atlantic and Pacific, reducing sailing distances for some laden and ballast routes.
2. Vessels with beam above 32.3 m (the old Panamax limiting dimension) can be designed without loss of flexibility, leading to economies of scale over traditional Panamax ship classes.
3. The relaxation of the beam constraint has been shown to have the potential to improve efficiency through better optimization of the hull form (Stott and Wright, 2011).

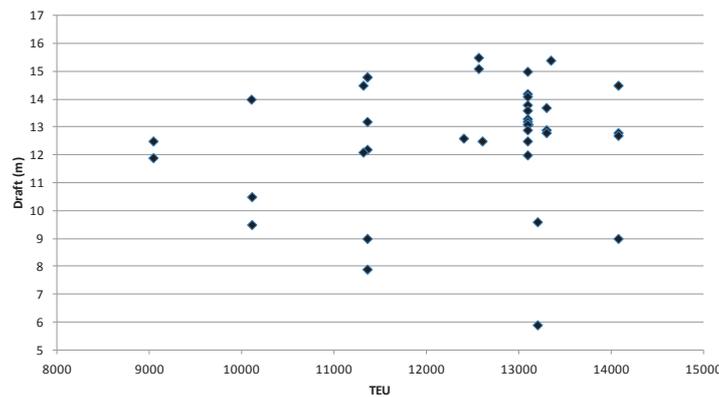
The following analysis considers the implications of the expansion separately for the three main ship types in the commercial fleet: container, dry bulk and tankers.

## 2. Container ships

The expansion programme is firmly targeted at increasing the transit of containers through the Canal (Panama Canal Authority (PCA), 2006), to maximise the economic benefit to Panama. The transit of container ships represents the most valuable sector to the Panamanian economy, generating over 50% of revenues (Panama Canal Authority (PCA), 2011) although accounting for only around one quarter of transits. Studies had predicted that this revenue was approaching a peak because the number of vessel transits was approaching the maximum potential capacity of the Canal and the only way to increase container transits further was to increase ship size and therefore the throughput of boxes per transit. The expansion programme anticipated an increase in the size of the largest container ship that can make the transit in laden condition from around 4,800 TEU under the existing constraints to around 12,000 TEU under the new constraints (according to the PCA's predicted figures).

The precise maximum size of container ship that can transit the expanded Canal is larger than originally envisaged, however. Taking into account the new limiting dimensions indicated in Table 1, the largest existing container ship with 366m length is about 13,200 TEU, having a beam of 48.2m (IHS Fairplay, 2012). Technical details on Sea-Web (IHS Fairplay, 2012) suggest that such a ship has

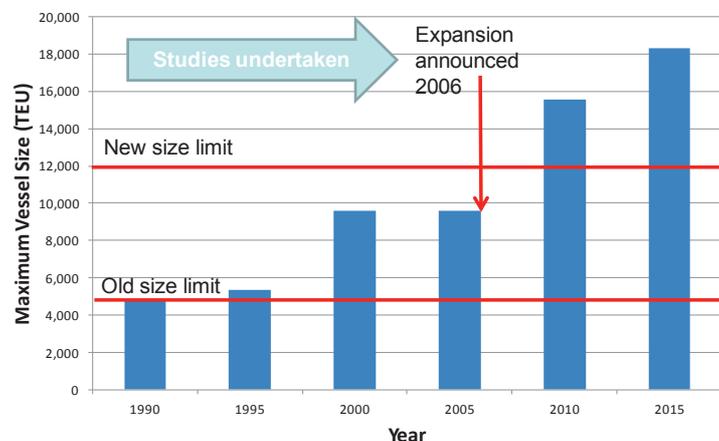
a draft of 15.5m, which is too deep for the expanded Canal. This is the ‘scantling draft’, however, that being the deepest draft consistent with the strength of the hull. The ‘design draft’, that is to say the draft dimension for which the ship is designed to operate, tends to be significantly lower than this. For example the 13,100 TEU vessel ‘*Maersk Edison*’, delivered by Hyundai Samho in 2011, has a scantling draft or 15.5m but a design draft, of 14.5m (Royal Institution of Naval Architects, 2012). Such a vessel appears to be an example of the new panamax class in the container sector. To confirm this assumption, actual operating drafts have been obtained from AIS data for a sample of container ships with 15.5m scantling draft (n = 39), reviewing reported actual drafts of ships in service on 12<sup>th</sup> July 2012 (Marinetraffic, 2012), with the results shown in Figure 1.



**Figure 1 – actual operating draft of 39 container ships with 15.5m scantling draft, on the afternoon of 12<sup>th</sup> July 2012**

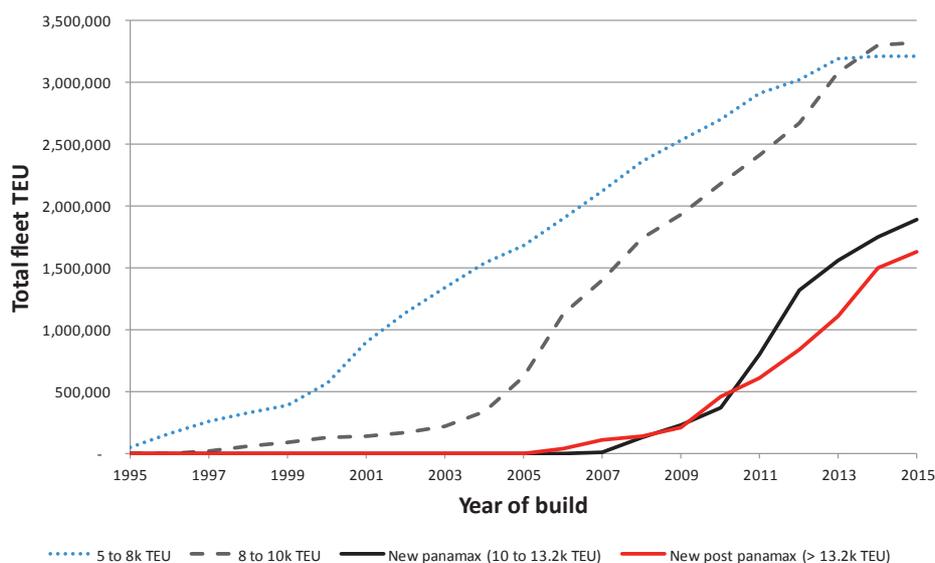
Only two vessels were indicating a draft above 15.2m, the new panamax constraint. The overall mean draft was 12.6m and median value 12.9m. A number of the vessels were found to be operating at unusually low drafts, including one vessel at anchor, presumably awaiting orders, with a draft at 5.5m. Ignoring all values below 11m, to obtain averages at normal operating levels, the mean draft was found to be 13.5m and median value 13.2m. These values support the contention that ‘*new panamax*’ in the container sector is a vessel of about 13,200 TEU, constrained by length.

It is interesting to review the development of container ship size in relation to the plans for expansion of the Canal. The Canal transferred from US to Panamanian jurisdiction at the end of 1999 and following a period of analysis and planning the expansion plan was announced in 2006. At that time a 12,000 TEU containership would have been regarded as very large. Figure 2 illustrates the development of maximum container ship size over time and shows how this relates to the old and new Panamax constraints (using the Panama Canal Authority’s estimate of the TEU limit of the expanded Canal at 12,000 TEU).



**Figure 2: the development of maximum container ship size in the context of the expansion of the Panama Canal**

The first post-panamax container ships started to appear in the early 1990s and by the end of that decade, at the point at which the operation and economic benefit of the Canal passed from the United States to Panama, the maximum vessel size had increased to around 9,600 TEU. It remained constant at this size for the next five years, up to the point that the expansion was announced. Over the subsequent five years the maximum ship size increased dramatically, with the introduction of so-called ultra-large vessels, to 15,550 TEU and by 2015, taking into account ships on order, the maximum size will have increased further to 18,330 TEU. The development of the ultra-large class of ships adds an extra level of complexity to the question as to how container trades will develop post-expansion. The development of post-panamax fleet capacity by ship size class is illustrated in Figure 3.



**Figure 3: the development of post-panamax container fleets since 1995, by size class**

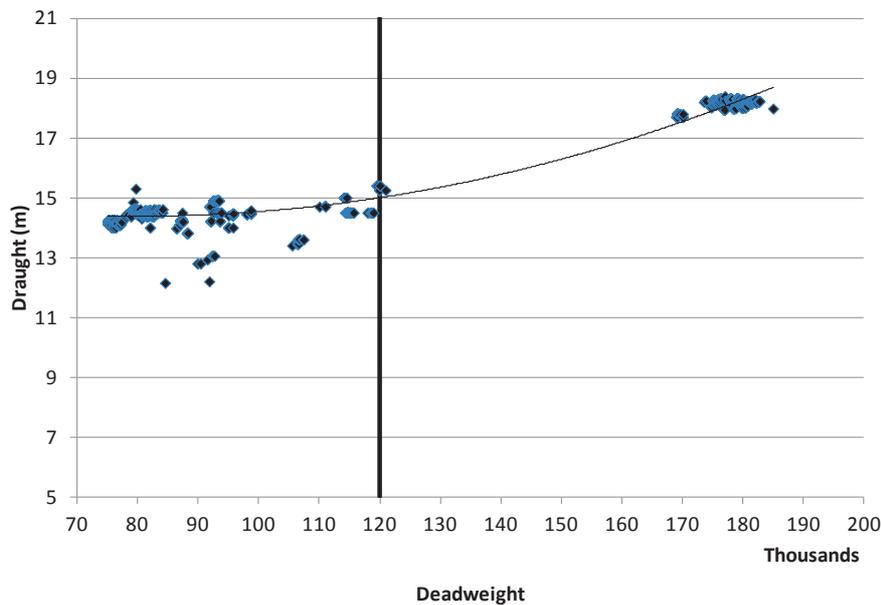
The capacity of larger ‘*new post-panamax*’ ships is almost equivalent to the ‘*new panamax*’ fleet, with the industry pursuing the economies of scale inherent in the ultra-large sectors. This does diminish the relevance of the Canal expansion to container trades, however. The 5,000 to 10,000 TEU sectors have grown significantly and the expansion presents the opportunity for these larger classes to ship containers through the Canal.

The economies of scale inherent in larger ships and the potential to route more boxes through the Canal will have a positive benefit on emissions. As indicated earlier it has not been possible to predict what the extent of the benefit may be in advance and the development of ultra-large ships in competition with the expanded Canal clouds this issue further.

### 3. Dry bulk carriers

The expanded Canal will be able to accommodate typical capesize vessels within the length and beam constraints but not within the draft limitation. A typical capesize of 180,000 deadweight tonnes has a length around 292m, beam 45m and loaded draft 18.2m (c.f. the limits presented in Table 1). This implications of this are firstly that the expanded Canal is effectively draft limited in the dry bulk sector (with both length and beam of typical capesize being within the new limits) and, secondly, that the capesize fleet will in future be able to consider the Canal as a routing option for ballast voyages, providing that this is economic. The decision on economic viability for such routing would depend not only on the vessel’s trading route but also the cost and availability of the Canal for a ballast transit.

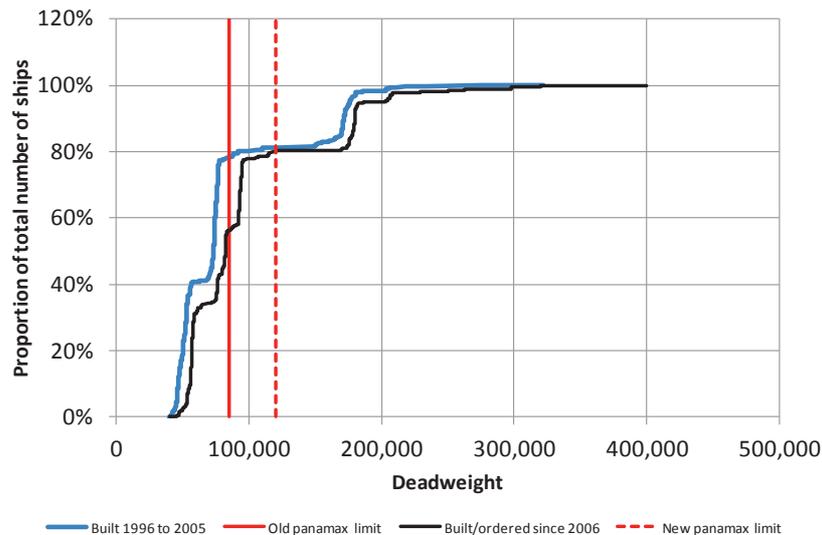
The draft limitation has been analysed using statistics from the existing fleet (IHS Fairplay, 2012) with the results presented in figure 4.



**Figure 4 – draft of existing bulk carriers, showing the limit of deadweight at 15.2m draft**

The analysis in figure 4 implies that the new panamax deadweight limit for dry bulk carriers is around 120,000 deadweight tonnes, compared to the current limit of between 80,000 and 85,000 deadweight tonnes. Such an increase would confer a significant benefit in terms of economy of scale and corresponding reduction in emissions per tonne mile transported, but only if shippers are able to make use of the larger tonnage. For container ships the unit of cargo is sufficiently subdivided to render the design of the ship effectively ‘inflatable’: that is to say that the capacity can effectively be increased to any particular size. In bulk shipping this is not the case and the vessel must be designed to economically transport the sizes of parcels that shippers wish to transport. For this reason the identification of discrete generic size classes in the container sector is difficult whilst it is an important feature of the bulk fleet, with fairly consistent handy, supramax, panamax and capesize designs.

The question of parcel size analysis in the bulk sector and whether or not shippers are ready for larger ships in the existing panamax trades was addressed in previously published work (Stott and Wright, 2011). The conclusion of this work was that the market is ready to make use of larger vessels, although the future size is not clear. The confirmation of this conclusion can be seen in ship ordering patterns when comparing the profile of bulk carrier sizes for the fleet built prior to the announcement of the expansion in 2006 with those built or ordered since. This is analysed in Figure 5.



**Figure 5 – Comparison of bulk carrier fleet size profiles comparing ships built before and after the announcement of the expansion of the Panama Canal**

It can clearly be seen from Figure 5 that prior to 2006 very few ships were built between panamax and capesize, that is to say between about 85,000 and 160,000 deadweight tonnes. For the fleet ordered since the announcement the emergence of new class of post-panamax vessels, between 85,000 and 100,000 deadweight tonnes can be clearly seen, with this class being designated ‘mini-cape’ by the market at the present time. Following the opening of the expanded canal this fleet is effectively the ‘new panamax’ sector. It can also be seen from Figure 4 that the market is currently cautious in terms of vessel size, with most vessels well below the new theoretical maximum limit of the canal. It is an un-written law of naval architecture, however, that ships tend to become larger over time (Buxton, 2004), as can be seen in the shift to the right of the capesize portion of the fleet in Figure 5, and the final size of ‘new panamax’ has yet to emerge.

Bulk carriers make up the largest sector of the deep sea fleet with panamax beam and the potential benefit to fleet efficiency and emissions is significant. There are around 4,600 bulk carriers with panamax beam (IHS Fairplay, 2012) of which 2,376 (52%) are what ship brokers term ‘panamax’ vessels, with deadweight over about 60,000 tonnes. The other half of the fleet is made up of smaller vessels where panamax beam is used to maximise the internal volume of so called ‘handymax’ and ‘supramax’ ships, up to around 55,000 deadweight tonnes. The expansion will facilitate the development of ships with improved economies of scale in the panamax sector but without compromising the flexibility (and thereby the asset value) of the vessel. It may also permit better optimisation of the hull form of smaller vessels, although a note of caution is required here. For such vessels an increase in beam may compromise their access to appropriate ship repair capacity (Stott and Wright, 2011) and increasing the beam in that sector should be undertaken with caution.

In summary the expansion of the Canal offers significant potential for improved efficiency and emissions reduction in the dry bulk sector, due to:

- Improved ballast routing options for capesize vessels.
- Improved hull optimisation for vessels of traditional panamax capacity<sup>1</sup>.
- Economies of scale through increasing ship size in the panamax sector<sup>2</sup>.

<sup>1</sup> Previous work tentatively estimated that this could improve fuel consumption by up to 5.5% (Stott and Wright, 2011).

<sup>2</sup> Potentially saving up to 16% per tonne mile with a pro rata saving in emissions (Stott and Wright, 2011).

#### 4. Tankers

The expanded Canal will permit transit of fully laden aframax vessels, the largest in this class having a deadweight of around 120,000 tonnes, with dimensions 250m length, 45m beam and 15.2m draft. As with the dry bulk sector, however, the limitation is set by draft and larger vessels will be able to transit in light or partially laden conditions. A typical suezmax crude oil tanker of 160,000 deadweight tonnes has length around 274m and beam around 48m but laden draught of around 17.0m. The expansion opens up the possibility that such vessels could transit in ballast, potentially offering improved routing efficiency on part of their voyage. This is of little significance for the major crude oil trade flows but may be of benefit on more minor routes. Relevant routes may include, for example US/Caribbean/Brazil to Asia.

Tankers constitute the second largest sector of the fleet with panamax beam, after dry bulk carriers, with around 1,800 vessels. This fleet is summarised by size class and ship type in Table 2 (IHS Fairplay, 2012), with size classes defined as being handysize below 60,000 deadweight tonnes and panamax above.

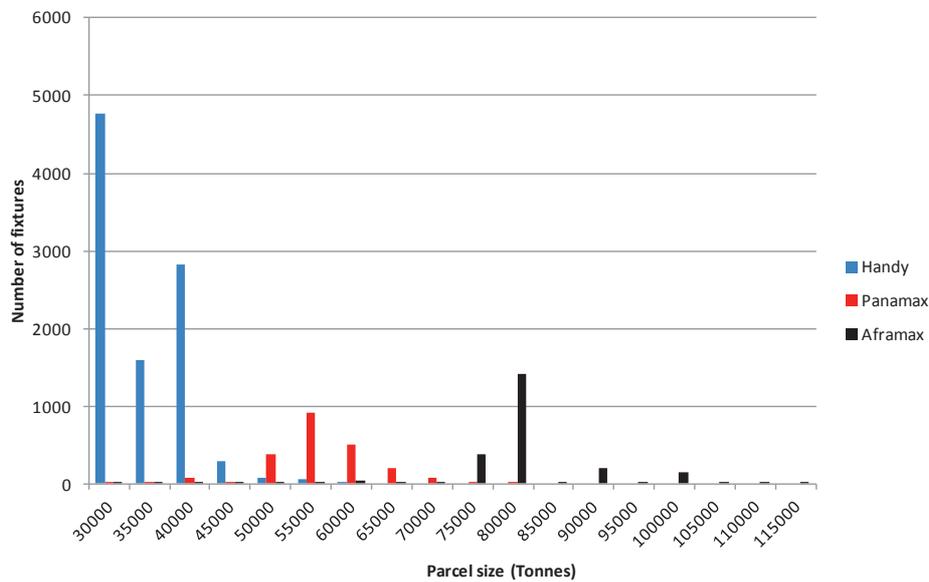
Ship type	Size class	
	Handy (< 60,000 dwt)	Panamax (> 60,000 dwt)
Chemical/Products Tanker	838	32
Crude Oil Tanker	2	45
Crude/Oil Products Tanker	122	135
Products Tanker	360	210
<b>Total oil tankers</b>	<b>1322</b>	<b>422</b>
Fruit Juice Tanker	4	
LPG Tanker	25	
Asphalt/Bitumen Tanker	1	
Chemical Tanker	9	1
Shuttle Tanker	4	3
<b>Total special tankers</b>	<b>43</b>	<b>4</b>
<b>Grand total</b>	<b>1365</b>	<b>426</b>

**Table 2: tankers with panamax beam in 2012**

It can be seen that only just under one quarter of this fleet is actually panamax size, with the limiting beam dimension being used predominantly to maximize hull volume in the smaller handysize sectors. The note of caution given above in the dry bulk section of this paper, referring to the limitations of ship repair capacity, should be taken into account in relation to this sector also, with any increase above panamax beam for smaller ships being very carefully considered. The number of actual panamax ships in the tanker sector is only around 18% of the number of ships with 32.3 beam and the potential for improvement in transport efficiency, and thereby the reduction of shipping emissions, is correspondingly relatively limited in this sector.

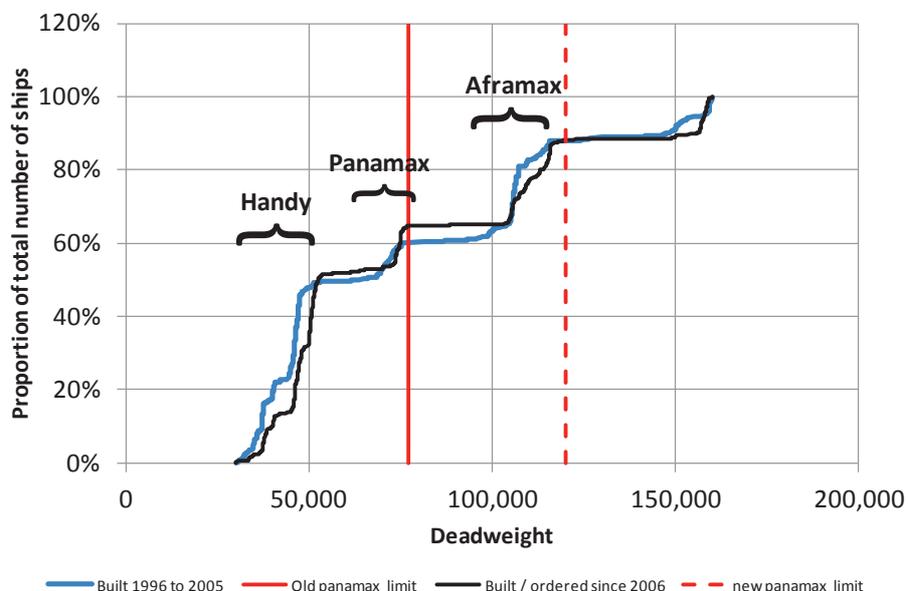
Panamax tankers operate predominantly in the oil products trades, along with handy and aframax vessels. The economic context has been analysed using records of 14,207 spot charters for products tankers in 2008 and 2009, published by the ship broker Clarkson (Clarkson Research, 2012). Reflecting the fleet make-up the spot trades are skewed towards the handy sector, accounting for 78% of all the fixtures examined. The remaining 32% was split evenly between the panamax and aframax sectors.

In all sectors the load factor, that is the ratio of parcel size to ship capacity, is around 78% and there is no indication in this or in the parcel size distribution function that the market is anxious to increase ship size. The parcel distribution function for products fixtures in 2008 and 2009 is shown in Figure 6.



**Figure 6: parcel size distribution function for 14,207 oil products spot charters in 2008/2009**

This conclusion is further confirmed by analysis of ship ordering patterns when comparing the profile of tanker sizes for the fleet built prior to the announcement of the expansion in 2006 with those built or ordered since, illustrated in Figure 7.



**Figure 7 - Comparison of tanker fleet size profiles comparing ships built before and after the announcement of the expansion of the Panama Canal**

It can be seen from Figure 7 that there has been no noticeable shift in the size of panamax tankers since the announcement. A shift can be seen in the average size in the handy range, with the

movement of the line to the right, and similarly in the aframax range, moving towards the new panamax limit of around 120,000 deadweight tonnes. The average deadweight of aframax vessels increased from 106,000 tonnes in the ten years prior to 2006 to 110,500 for ships ordered or delivered since that time. The expansion therefore appears to be of greater significance to the aframax sector than the panamax sector.

In summary the expansion of the Canal offers potential for improved efficiency and emissions reduction in the tanker sectors, but this is likely to be less than in the container and dry bulk sectors because of the smaller fleet size. Improvements may be due to:

- Improved ballast routing options for suezmax vessels in the crude oil trades.
- Improved hull optimisation for vessels of traditional panamax capacity.
- Economies of scale through increasing ship size in the aframax sector or from greater use of aframax tonnage in place of panamax tonnage in oil products trades.

## 5. Conclusions and further work

The expansion of the Panama Canal provides opportunities for reduction of emissions from shipping, stemming from improvements in ship design, economies of scale and improved routing opportunities.

In terms of ship design the shape of new panamax vessels has become clear, summarised in Table 3.

Sector	Existing panamax	New panamax
Container	<ul style="list-style-type: none"> <li>• About 4,800 TEU</li> <li>• Beam-limited</li> </ul>	<ul style="list-style-type: none"> <li>• About 13,200 TEU</li> <li>• Length-limited</li> </ul>
Dry Bulk	<ul style="list-style-type: none"> <li>• About 85,000 dwt</li> <li>• Beam-limited</li> </ul>	<ul style="list-style-type: none"> <li>• Capesize in ballast</li> <li>• About 120,000 dwt laden</li> <li>• Draft-limited</li> </ul>
Tanker	<ul style="list-style-type: none"> <li>• About 80,000 dwt</li> <li>• Beam-limited</li> </ul>	<ul style="list-style-type: none"> <li>• Suezmax in ballast</li> <li>• About 120,000 (aframax) laden</li> <li>• Draft-limited</li> </ul>

**Table 3 – summary of changes to panamax vessels**

What is clearly missing is the analysis of what these changes mean to shipping’s transport efficiency and quantification of the potential reduction in emissions. The analysis of improvements due to ship design changes is perhaps more achievable than the analysis of routing implications, which has thus far proven elusive. It is likely that the savings will be significant, however, and work to achieve this quantification is recommended.

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