CASCADING FEEDER VESSELS AND THE RATIONALISATION OF SMALL CONTAINER PORTS

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Abstract

Small container ports rely on feeder services from hub ports to provide access to unitised trade flows for their hinterlands. They generally possess limited water depth and handling facilities, as investments required to handle larger vessels are not justified by their low container throughput. This paper questions the future of small ports due to larger vessels cascading down as a result of ever-larger vessels on the major trade lanes.

The paper uses vessel call data to identify all world ports currently served by sub-1,000 TEU vessels. Data on the dimensions of the vessel fleet and order book are analysed in conjunction with accessibility constraints at these small ports. Results show that with 15% of the sub-1,000 TEU fleet currently laid up and very few on order, larger feeders with deeper drafts seem certain to serve at least some of these routes. But with 90 container ports (21%) having berth depth of less than 9.1m and the need to accommodate design drafts of at least 8.7m, larger vessels will threaten the viability of these ports unless they commit significant investment. A geographical analysis is also conducted, mapping the distribution of small ports across the globe and classifying coastal, estuary, river and island locations, as well as identifying clusters of small ports that could in future be served by second-tier hubs, such as Southeast Asia and the Baltic Sea.

Findings suggest that, just as container ports at the larger end of the scale were rationalised as flows concentrated at major hubs, several drivers exist for the same process to occur at small ports. Consequently, the paper asks how small ports and local shippers will cope, whether such ports lose their connections entirely, if local shippers must pay for an additional handling cost to tranship a second time from large feeder to small feeder, or whether they rely on overland transport links.

Keywords: container ports; shipping lines; carriers; vessels; feeders; short sea shipping (SSS)

1. Introduction

As container ships grow ever larger to achieve greater economies of scale and hence cost savings, ports expand to be able to handle them. This expansion occurs both in terms of physical size of berths and the speed and efficiency of handling the large drops of containers that must be moved in and out of the port gate and through the hinterland. Port systems evolve according to these trends, resulting in concentration of container movements at a handful of hub ports within each range, and flows are then feedered to other ports according to a variety of schedules devised by carriers to balance their vessels and containers.

Feeder ports generate enough cargo to require shipping services, but not enough to require large vessels, and remain sufficiently distant from larger ports in the same range that under current market conditions the larger ports cannot serve this hinterland profitably overland. So smaller ports continue to serve their local markets, connected to transhipment-only or hybrid ports by small feeder vessels. They generally possess limited water depth and handling facilities, as large investments required to handle larger vessels are not justified by their low container throughput. The question asked in this paper is how long this situation will continue. Are current trends for larger vessels likely to threaten this model? Will smaller vessels disappear entirely, meaning that small ports will lose their connections unless they upgrade their facilities? Or will shipping lines continue to serve these ports via the insertion of second-tier hub ports where cargo is transhipped from large to small feeder? While there are several demand-side influences on port systems such as the global economy and regional trade specialisations, this paper looks at the supply-side influences, in particular the supply of shipping services.

Recognising the challenges in data availability and quality (discussed in the methodology), this paper takes a somewhat descriptive approach to identify and classify small ports, before analysing them within a framework drawn from previous conceptualisations of port system evolution. The methodology is based on analysis of a monthly sample of vessel call data. First, small container ports across the globe are identified, defined for the purposes of this paper as those ports currently served by sub-1,000 TEU vessels. Data on the sub-1,000 TEU vessel fleet and order book are then analysed in conjunction with accessibility constraints at small ports across the globe. Depth is the main focus in this analysis as it is the key metric in many port expansions, although of course berth length is also important as is access infrastructure such as locks which are not uncommon in small ports. A geographical analysis of small container ports is then performed, identifying coastal, estuary, river and small island ports. Potential consequences are considered regarding the role of small ports in the evolution of port systems and a research agenda is established.

Section 2 reviews the literature on the evolution of port systems, before a discussion of the role of small ports, feeder networks and capacity utilisation in the port sector in section 3. Section 4 outlines the methodology and data sources, while section 5 presents results. Section 6 discusses potential strategic responses by small ports and section 7 concludes by establishing a research agenda.

2. The evolution of port systems

Over the last 30 years, several factors have caused a shift in world port traffic from using a spread of ports in a range based primarily on proximity to sources of production or consumption to a situation where a small number of large hub ports in a range dominate traffic in a region. Conceptualisations of port system evolution have developed from traditional spatial analyses of port expansion and upgrading of berthing and handling facilities (Bird, 1963; Taaffe et al., 1963; Rimmer, 1967; Hoyle, 1968; Hayuth, 1981; Barke, 1986; Van Klink, 1998) to the more recent focus on port competition through hinterland accessibility (Notteboom & Rodrigue, 2005; Monios & Wilmsmeier, 2012a). Other influences on port system evolution include the competition in the maritime foreland, focusing on intermediate transhipment hubs and the structure of maritime services (Sanchez & Wilmsmeier, 2006; Rodrigue & Notteboom, 2010), and in particular the role of the concentration of liner services (e.g. Frémont & Soppé, 2007; Lee et al., 2008; Wang & Ducruet, 2012).

Increased economies of scale available from ever-increasing ship size was a key driver for shipping services to be rationalised, whereby large vessels traversed major routes between a limited number of hub ports. Cargo was then sent inland or feedered to smaller ports. The key factor for ports has been intermediacy, as ports changed from city-based centres of local trade to major hubs for cargo to pass through, with distant origins and destinations. This development has been driven to a large degree by the container revolution, as distribution centres based far inland have become key cargo generators and attractors.

Several scholars have discussed the process of concentration in port systems, followed by a trend towards deconcentration (Hayuth, 1981; Barke, 1986; Slack & Wang, 2002; Notteboom, 2005; Frémont & Soppé, 2007; Ducruet et al., 2009; Wilmsmeier & Monios, 2013). This process results in significant challenges to port infrastructure and superstructure, and to connecting hinterland infrastructure. The deconcentration observed in recent years by some authors (e.g. Wang and Ng, 2011, in China; Wilmsmeier and Monios, 2013, in the UK; Wilmsmeier et al., 2014, in Latin America) has in some cases driven the emergence of secondary ports, able to insert themselves as second-tier regional hubs, between large hub ports and smaller local ports. This role becomes possible because, as container ships on the main routes get larger and container drops at each call increase, hub and spoke and interlining networks become more complex. This process of deconcentration in turn may be expected to lead to concentration at small ports because some will lose traffic to these new second-tier hubs. This paper examines some influences on this process by analysis of container vessel sizes, the increases in which show no signs of stopping. Not long after 16,000 TEU and then 18,000 TEU ships became the accepted maximum, orders are now being placed for 20,000+ TEU vessels (e.g. in March 2015, MOL placed orders for six 20,150 TEU vessels). Designs for at least 22,500 TEU ships are actively being considered, as small profit margins force operators to pursue ever greater scale economies. The question has now become not the feasibility of the vessel itself but whether the supporting system can cope.

While the majority of the literature analyses large ports, the complexities of modern liner shipping mean that the roles of small and medium ports are ever changing. The interest of this paper is how the cascading effect of vessels down from the larger to the smaller trades will affect port choice and hence access to containerised flows for shippers currently served by small container ports. One of the early writers on this topic, Hayuth (1981; p.160), noted that "it is difficult to weigh the importance of each factor in the development of a load centre port, but a large-scale local market, high accessibility to inland markets, advantageous site and location, early adoption of the new system, and aggressiveness of port management are major factors to consider". These factors are generally applied to large ports but they can be reinterpreted in relation to small ports to form the framework for the research undertaken in this paper.

3. Vessel utilisation, feeder shipping and the role of small container ports

Capacity utilisation is an ongoing challenge for shipping lines, although a distinction should be drawn between a certain level of slack built into the system to accommodate peaks and troughs and genuine situations of overcapacity. After the onset of the global recession in 2008, demand shrank just as large amounts of vessel capacity entered the market, leading to over capacity and the resulting plunge in freight rates and charter rates. This was due to the cyclical nature of shipping and the time-lagged nature of large investments, meaning that vessels ordered at the peak of the market when rates were high and capacity was stretched came online as the market turned downwards. More slowly but just as noticeable was the arrival of additional port capacity. In regions where under capacity had led to a loss of traffic to competitor ports (e.g. UK ports losing traffic to continental European ports), major terminal expansions came online at a time of overcapacity, and some expansion plans were delayed or cancelled.

Similarly, vessel orders slowed, older vessels were scrapped early for a fraction of their value, slow steaming was employed to absorb excess tonnage where possible and many vessels were laid up.

While mid-size vessels can be redeployed on other routes (as will be discussed shortly), the largest vessels cannot. These are limited not only to a single trade (Asia-Europe), but to a handful of specific ports, due to handling limitations either in the port or from the associated container distribution. Ports invest large sums upgrading their facilities and competing to receive vessel calls, but handling such demand spikes is difficult. Large container drops can result in inefficient crane utilisation, as the numerous large cranes required to service large ships are not all required between calls; furthermore, such numbers of containers cannot always be moved in and out of the port in a smooth manner. It has been estimated that a 19,000 TEU vessel dropping 8,800 TEU in a single call will necessitate 14,000 container moves, six 800 TEU feeders, 53 trains (carrying 90 containers each), three 96 TEU barges and 2,640 trucks (Grey, 2015).

Shipping lines already cannot meet their own schedules; current average reliability across the industry is below 70%. The larger the vessel and the larger the drop of containers at each call, the larger the knock-on effect of such poor reliability on the rest of the container system. Going back to Bird (1963; p.33): “The ship designer has always been the pacemaker in shipping transport innovations since his creation has merely to float and sail economically per ton mile; whereas the port engineer has to cope not only with the demands of ship designers, but also with the physical difficulties of the port’s land and water sites.” It remains far from clear whether increasingly large container vessels are good for the industry and may in fact result in diseconomies rather than economies of scale. Yet pessimists have predicted a peak in vessel capacity for years and been proven wrong so quite possibly the industry will find a way as it always does.

Due to these difficulties, the newest generation of container ships inherently represent a greater risk for the owner, be they a lessor or operator, as the cost of around $USD150+m for one vessel is a significant outlay that must be recouped. Vessel owner Seaspan is currently demanding 15-year charter contracts with prospective operators before they will order 18,000 TEU vessels from the shipyards, due to the risk of being left with such vessels after around 10 years and unable to find an interested operator to lease them (Porter, 2015).

The dominant Asia-Europe trade remains the driver for the largest class of container vessels, and while increased traffic on other trades induces expectations that they will be served by larger vessels in future (e.g. Sánchez & Perrotti, 2012), there is some concern that larger vessels are being cascaded too soon, simply because of the carriers' need to soak up excess tonnage, leading to dramatic underutilisation on some routes (Wilmsmeier, 2013).

Other perhaps unexpected results of the cascading resulting from the introduction of ultra-large container ships are the introduction of entirely new routings. In March 2013, Maersk found it more economic to switch 9,000 TEU vessels from Asia-Europe to Asia-USEC via Suez, rather than their previous solution of using Panamax vessels to link Asia and USEC via the Panama Canal. The new routing is longer but the larger vessels recoup earnings through economies of scale, in addition to providing a solution to absorb the tonnage cascaded down from the Asia-Europe route (Porter, 2013). Total capacity is, however, not the only issue as design specifications also exert significant influence. Due to past limitations of the Panama Canal, the original Panamax design was long and thin, to maximise capacity within draft and width restrictions (capacity of up to 5,000 TEU, depending on design). Post panamax was the next generation, used exclusively for Asia-Europe or Asia-USEC. Widening of the canal will allow Post panamax and up to New panamax (around 13,000 TEU) to traverse this route, meaning that old Panamaxes are being cascaded down to other routes. The problem is that their longer design makes them less suited to cascade down to medium ports with shorter berths. This is reflected in a sharp drop in charter rates, for example a recently renewed charter dropping from $23,250 per day to only $9,900 (Lowry, 2014). Such rates are unsustainable and likely to result in such vessels being taken out of service eventually, except in cases where it proves economic to have them widened.

In addition to simply using up excess tonnage, shipping lines obviously prefer the economies of scale to be gained from larger vessels where possible. Regulatory influences that lead to increased fuel price (e.g. SECA regulations requiring the use of more expensive low sulphur fuel or the use of scrubbers) will also encourage this decision, as such investments are better spread over more containers hence fewer, larger ships are desirable. Also, owners of older smaller feeders will be reluctant to invest in upgrading them so they will be moved elsewhere and newer feeders introduced are likely to be larger.

From the perspective of small ports, cascading of vessels presents a much more serious problem. If even medium traffic routes can expect to be served by vessels too large for their traffic, the case is even more acute for the trades below them, currently served by vessels around 4,000 TEU. Below that level are 2-4,000 TEU routes, and, finally, small feeder routes currently served by sub-1,000 TEU vessels, which are the focus of this paper.

Some ports are so small that it is not worth developing container vessel handling infra- and superstructure, so they are served by geared container vessels or by general cargo vessels with some container capacity handled with mobile cranes. These ports represent a different segment that will no doubt continue with this model. This paper addresses ports that are large enough that they are fully functional container ports already but are small enough that increasing ship size will affect them.

As noted above, the introduction of new vessels on mainline routes can be expected to initiate a process whereby vessels cascade down to other trades, which may continue down to the smallest feeder routes. In addition, busy ports handling large vessels may not occupy valuable berth space with small feeder vessels below 1,000 TEU. Thus feeder routes linking small container ports with transhipment hubs may in future be served by "super feeders" in the range of 2,000-4,000 TEU, which would mean some small ports have insufficient handling capacity to accommodate them. As noted in previous research, such a situation would support the growth of regional second-tier hubs linked to main hubs, which can then serve the smaller ports either by smaller feeders or even land transport (thus raising issues relating to the quality and capacity of hinterland infrastructure links). The likely reality is a combination of the above strategies at different ports across the globe. This paper will analyse the relevant data to explore these possibilities and consider the future for small container ports as a result of these decisions.

4. Methodology

The first decision for the methodology was how to identify the set of small container ports, defined as those ports currently served by container vessels but with limited depth that will put them at risk if vessel size increases. The initial set was selected based on current calls by sub-1,000 TEU vessels before analyzing required draft for these vessels and available berth and channel depth at each port. While it may seem intuitive to select small ports initially either by their throughput or their depth rather than the chosen approach of vessel calls, using throughput and depth would require arbitrary choices for the cutoff point, and indeed would either produce the same eventual set anyway or could even potentially miss some ports from the set. Choosing ports by throughout would require an arbitrary decision for setting the cut-off point. For example, a point of 100,000 TEU or 200,000 TEU would have missed several ports in the set with higher throughput. In the best case scenario, the same set would be identified anyway, so there is no advantage to that method. Similarly, identifying the set based on depth is only possible if the relevant vessel draft is known in order to set the cutoff point, which can only be done by looking at the vessel dimensions, which again would produce the same set of ports.

Moreover, data availability and formats make depth analysis difficult. It is not possible to obtain a reliable total list of ports by depth, for two reasons. First, the sources used in this analysis (discussed in the next paragraph) often disagreed and in many cases the value for maximum berth depth in one or more of the three primary sources was very far wrong. Second, ports have numerous berths so most sources will list all of them and each one must be examined manually to find the correct figure. Compounding the issue is that many ports, especially the small ones analysed in this paper, are spelled differently in different sources. Manual inspection of a minimum of three sources for berth and channel depth was required for all of the 436 ports identified from the vessel analysis. Each port was also visually inspected on Google Earth and port websites to identify and classify their location attributes. Even many of the vessels had to be checked individually against more than one source to double check their draft and TEU capacity as data sources do not always agree. So, while to some extent the results in the paper are descriptive, significant value lies in obtaining findings that could not be produced in any other way.

The first step in the analysis was to analyse port calls by small container vessels (sub-1,000 TEU), to identify which ports around the globe are handling them. This was done using a monthly sample of data from Lloyd's List for all world ports collected during November 2014. Berth and channel depth were obtained from a range of sources. The database was based first on the World Ports Index (which is why the segmentation in the depth analysis is based on the WPI format), and then every port was checked against Lloyd's List, FindaPort and port websites. This was done for two reasons: first, to check for inaccuracies and correct where necessary, and second, because, in addition to channel depth, the specific depth of the largest container berth was needed. The maximum container terminal berth depth was taken for all of the ports (e.g. if a port has three container terminal berths of varying depths then the deepest was taken). In cases where the value could not be confirmed from two sources it was removed from the dataset, therefore the channel depth analysis is based on 368 ports and the berth depth on 420 ports, out of a total of 436 ports served by sub-1,000 TEU vessels.

The second step was to identify the dimensions of the sub-1,000 TEU vessels in the sample. Due to varying ship designs, the same TEU capacity vessels may have different drafts, which is especially true for smaller vessels. Vessel dimensions were primarily obtained from Lloyd's List, with some gaps filled by other sources such as Marine Traffic, Vesselfinder and Alphaliner.

The third step was to analyse the world fleet and order book by vessel size, to identify trends in smaller vessels being laid up, scrapped and not replaced. These data were obtained from Containerisation International. Finally, the above results could be combined in order to determine what would happen to the sample of "at risk" ports if minimum vessel size increased. This was done by comparing port dimensions against vessel dimensions for a range of TEU capacity. Mapping the ports also enabled a geographical analysis of coastal, estuary and river ports and a comparison of geographical world regions.

5. Results

5.1 World ports currently served by sub-1,000 TEU vessels

The first step is to analyse port calls by small vessels (sub-1,000 TEU) to identify which ports are receiving them. These results can then be segmented into 0-499 TEU and 500-999 TEU and ports grouped by geographic region. The dataset shows that in November 2014, 707 ports across the world handled container vessels. Of these, 436 ports in 119 countries were served by sub-1,000 TEU vessels (see Table 3 in the appendix). The majority of countries only have 1-2 ports serving such vessels but 20 countries had 5 or more, while those with more than 10 were Japan 43, China 37, Indonesia 22, Spain 20, UK 17, Italy 15, Russia 13, Norway 12 and South Korea 11. Most of these countries have many small islands hence a large number of small ports.

Feeder vessels link hub ports with small ports, so a full list of ports served by sub-1,000 TEU vessels shows both. Therefore, the next step is to look at port depth to identify the smaller ports. Berth depth[1] across the sample is shown in Figure 1.

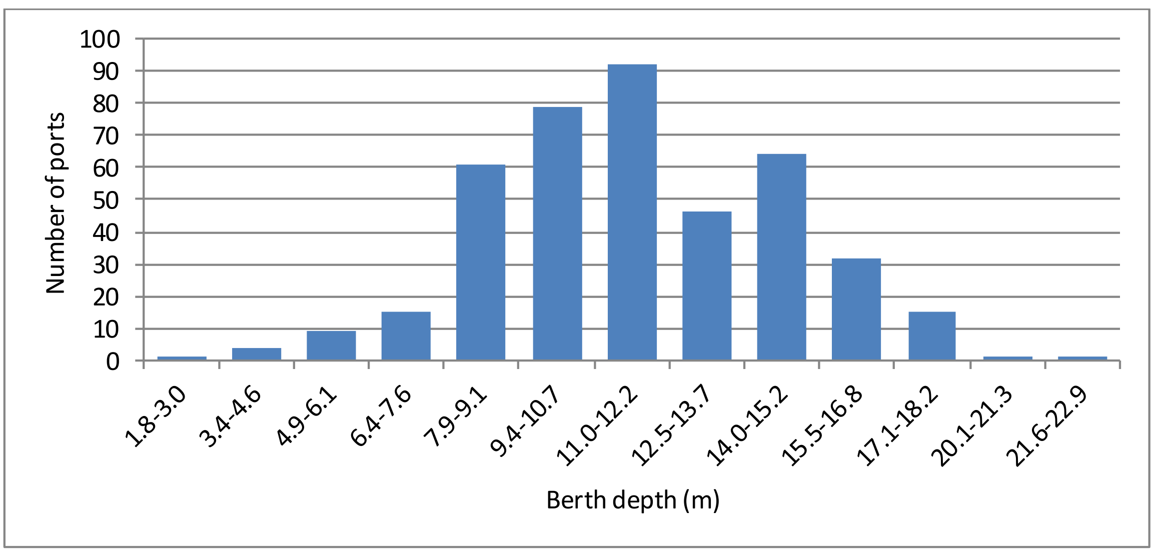

Figure 1 - Berth depth at container ports handling sub-1,000 TEU vessels

[1] All berth and channel depth analysis is based on the segmentations used by the World Port Index, one of the key data sources. Any ports with unknown berth or channel depth were excluded from the analysis.

The figure reveals a range of maximum berth depths at the ports, from 29 world ports with berth depth less than 7.6 metres to the handful of world container ports with very large depth (around 16m is required for the largest class of current container vessels). Channel depth is more significant (Figure 2), as deepening a berth is a smaller task than dredging an entire access channel.

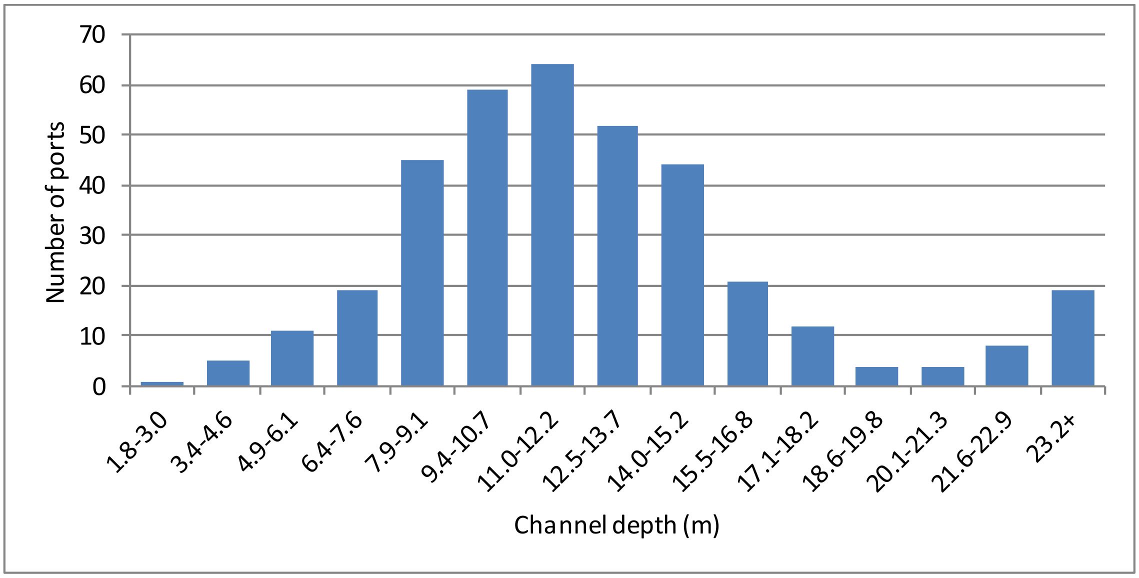

Figure 2 - Channel depth at container ports handling sub-1,000 TEU vessels

Channel depth is a difficult dataset to analyse, because the tidal variation may add a few metres to the actual draft of vessels that may use the channel. An interesting result from the data is that, at the deeper end of the spectrum, more ports have deep access channels than have deep berths, due to naturally deep water locations as opposed to those that have been dredged. As regards the focus of this paper, the data show that a significant minority of ports have rather shallow access channels (36 container ports less than 7.6m). The next step is to analyse vessel size and a later section will cross reference vessel drafts with the port depths above to identify ports at risk.

5.2 Vessel dimensions in the sub-1,000 TEU fleet

The second step is to identify the dimensions of the sub-1,000 TEU vessels in the sample. Due to varying ship designs, the same TEU capacity vessels may have different drafts, which is especially true for smaller vessels.

Section 5.1 showed berth and channel depth at all container ports currently served by sub-1,000 TEU vessels, revealing an average maximum berth depth of 12.3m, with 90 ports out of 436 less than

9.1m and 29 ports less than 7.6m. The sample of sub-1,000 TEU vessels shows an average length and beam of 127m and 20m, and an average design draft of 7m. Compared to the new generation of ultra-large container ships with dimensions of around 400m long, 58m wide and a draft of 16m, such vessels are around one-third the size, but since they carry only 5% of the containers, the economies of scale from larger vessels are obvious. Data analysis shows that length increases significantly with capacity, from an average of 115m at 500 TEU to 149m at 1,000 TEU. This may be significant for a small port, whereas an increase of beam (from 19m at 500 TEU to 23m at 1,000 TEU) tends to be less of a difficulty.

The key statistic for the analysis is the number of vessels at each draft range (Figure 3). The figure reveals that the range of drafts for the majority of sub-1,000 TEU vessels is around 6-9 metres. This is the design draft, so the actual depth required in the port channel and berth is larger, but this will depend on other factors such as how heavily laden the vessel is, the use of the tide to get the vessels to and from the berth and whether suitable anchorage is available if the tide is missed. Looking at average design draft over time (Figure 4), a large variation is in evidence, though with a downward trend for more recent 0-499 TEU vessels.

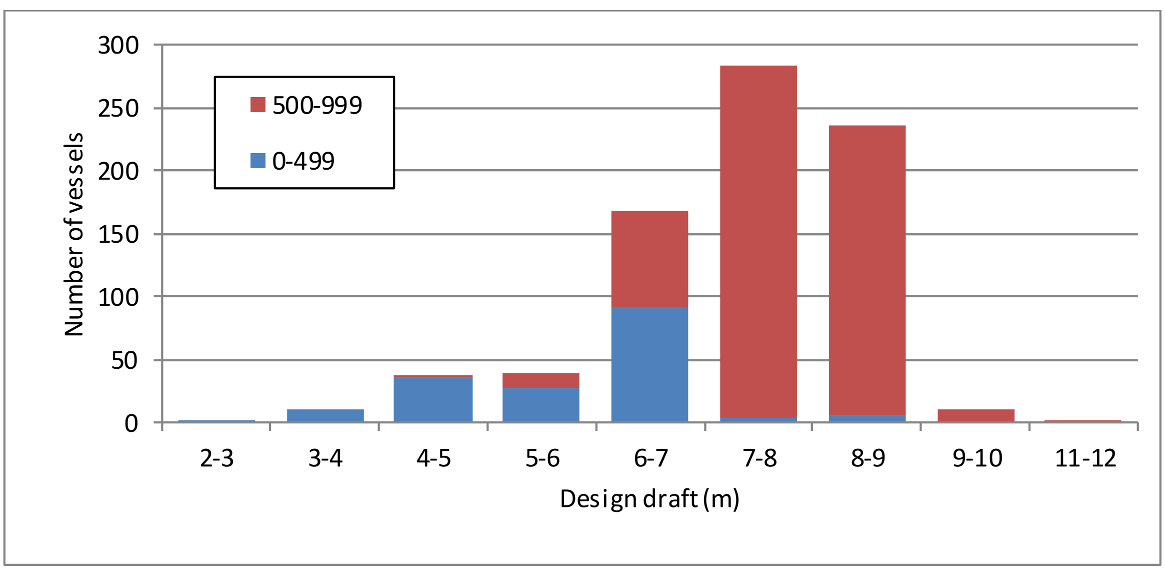

Figure 3 - Number of sub-1,000 TEU vessels at each draft range

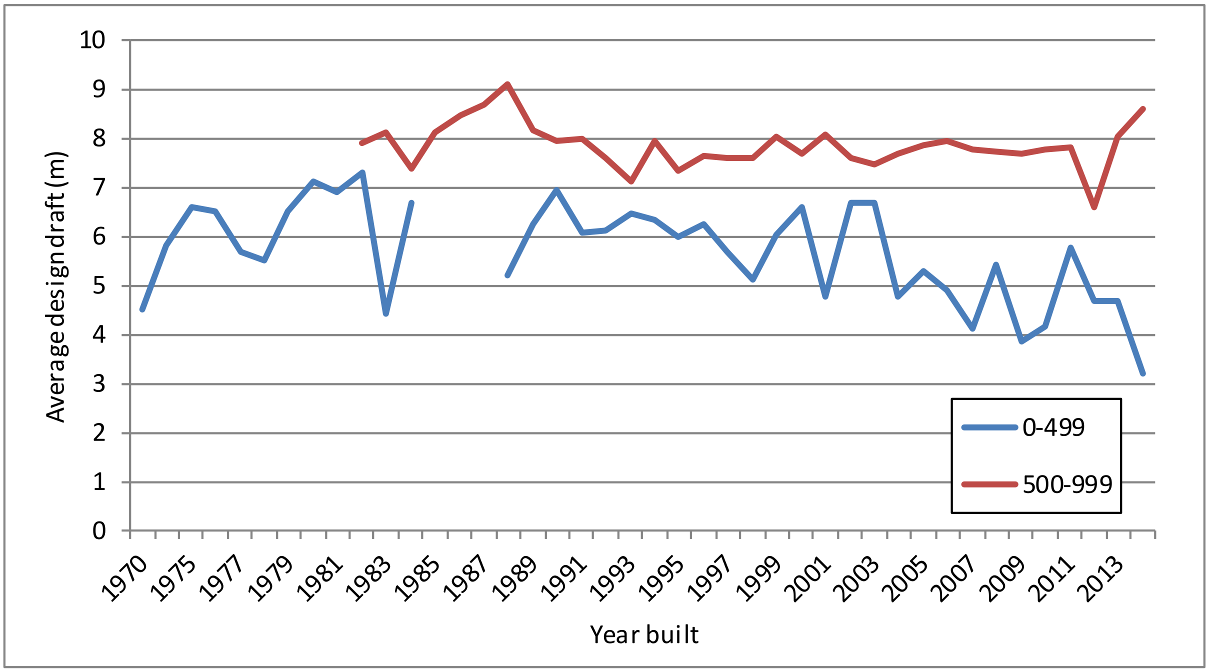

Figure 4 - Average design draft over time for sub-1,000 TEU vessels

Given, however, that there are far more vessels in the 500-999 TEU range, the overall average draft of newbuilds in the entire sub-1,000 TEU sample has increased slightly over time. What is more relevant is the fact that draft increases with capacity (Figure 5).

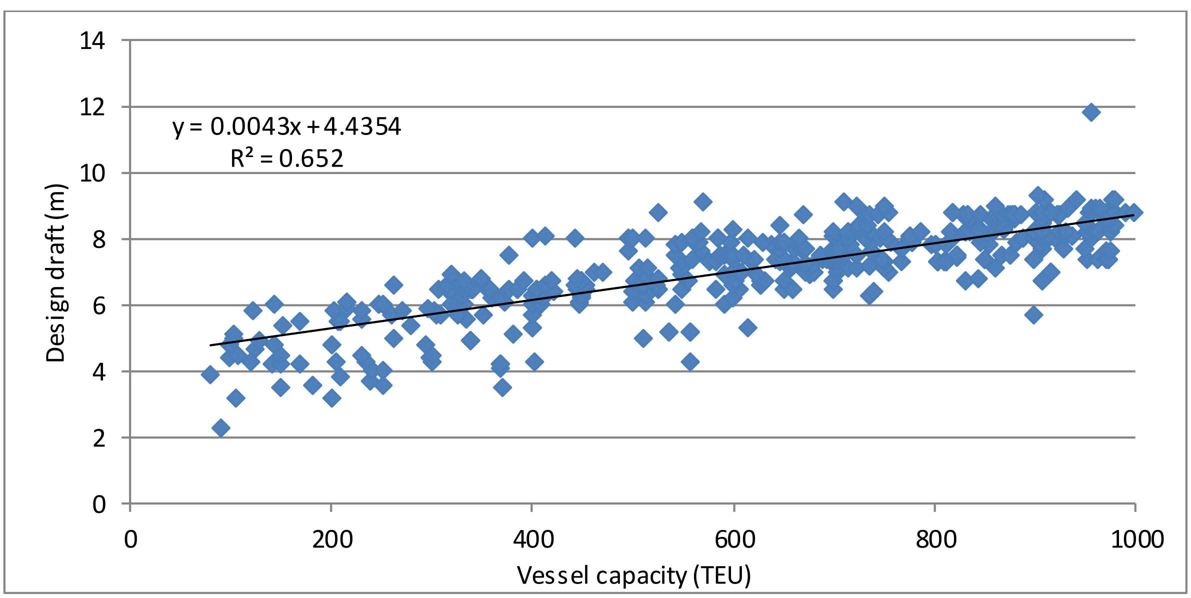

Figure 5 - Relation between design draft and TEU capacity

According to the line of best fit, an average design draft of 8.7m is expected of 1,000 TEU vessels, and that is not taking into account the maximum depth required by a fully laden vessel. Port analysis in a previous section indicated that around 90 of the sample ports did not meet this criteria, thus if vessels of this size and larger become the norm on feeder routes, such ports will face a challenge.

5.3 Status of the sub-1,000 TEU world fleet

The third step is to analyse the world fleet and order book by vessel size, to identify trends in smaller vessels being laid up, scrapped and not replaced. Table 1 shows the current world fleet of cellular container vessels.

Table 1 - World cellular fleet November 2014

TEU range	In service Nov 2014		On order 2014		On order 2015		On order 2016+		Total vessels on order	Total TEU on order
	No.	TEU	No.	TEU	No.	TEU	No.	TEU		
0-499	322	87,839	0	0	3	350	0	0	3	350
500-999	717	542,760	0	0	5	3,806	2	1,247	7	5,053
1,000-2,999	1,853	3,351,086	15	25,649	78	148,070	67	125,888	160	299,607
3,000-4,999*	924	3,819,588	4	16,505	13	50,710	9	34,600	26	101,815
5,000-7,499	618	3,727,315	2	11,900	9	54,201	0	0	11	66,101
7,500-9,999	371	3,198,982	3	26,200	69	620,786	26	240,448	98	887,434
10,000-12,999**	83	904,846	0	0	16	165,800	11	112,020	27	277,820
13,000-15,999	148	2,006,158	0	0	24	338,350	35	494,350	59	832,700
16,000+	20	336,670	1	18,400	30	538,110	10	191,000	41	747,510
Total	**5,056**	**17,978,594**	**25**	**98,654**	**247**	**1,920,183**	**160**	**1,199,553**	**432**	**3,218,390**

Source: Containerisation International

Note: * Old Panamax ** New Panamax

The table reveals that sub-1,000 TEU vessels account for 3.5% of the world fleet by TEU but 20.5% by number of vessels. What is particularly interesting is the order book, which shows very few small vessels on order. Only 10 out of 432 vessels or 5,403 TEU out of 3,218,390 TEU (0.17%) currently on order will be sub-1,000 TEU. The majority of the orders are in the range of the largest vessels, which will exert significant pressure to cascade vessels downwards. Significantly, the 1,000-2,999 TEU range continues to be popular, and using them on smaller routes will grant increased flexibility to operators. The obvious conclusion to be drawn from the data is that shipping lines do not appear to require new smaller vessels. This is explained by analysis of current tonnage laid up during November 2014 (Table 2).

Table 2 - Vessels laid up November 2014

TEU range	Owner operator		Chartered/ unknown		Total		% of total fleet
	No.	TEU	No.	TEU	No.	TEU	
0-499	19	6,702	73	16,399	92	23,101	26.43
500-999	9	6,128	54	38,349	63	44,477	8.19
1,000-2,999	16	26,329	34	50,823	50	77,152	2.30
3,000-4,999	3	13,678	3	12,811	6	26,489	0.69
5,000-7,499	1	6,435	4	23,610	5	30,045	0.81
7,500-9,999	2	18,000	7	60,442	9	78,442	2.45
10,000-12,999	0	0	0	0	0	0	0
13,000+	0	0	1	14,000	1	14,000	0.60
Total	**50**	**77,272**	**176**	**216,434**	**226**	**293,706**	**1.63**

Source: Containerisation International

Slow steaming is one way to absorb excess tonnage, but when no use can be found and it is not worth selling or scrapping them, vessels are simply laid up in safe anchorages. Table 2 shows that the situation has improved markedly from recent years, with a total of 226 vessels or 1.63% of the total fleet laid up. By comparison, in 2009 around 600 container vessels were laid up, and by early 2013 that number had almost halved to 333 ships or 6.6% of the container fleet (Wackett, 2013). Much of this reduction was due to scrapping of vessels rather than them re-entering service, and this was particularly so in the case of sub-1,000 TEU vessels; in 2012, 39 of these were scrapped against 8 delivered (Wackett, 2013). What is particularly interesting in terms of the current analysis is that in January 2013, 164 of 333 idle ships (49.8%) were sub-1,000 TEU, compared with 155 out of 226 (68.6%) in November 2014. This shows that sub-1,000 TEU vessels remain the most difficult to utilise.

Another interesting point is that non-operating owners account for the majority of idle vessels, with 78% of vessels and 74% of TEU capacity. Thus shipping lines relying mostly on chartered vessels were able to end charters and cut losses rather than being caught with expensive investments.

Table 2 shows that 26% of sub-500 TEU vessels are laid up. Carriers understandably prefer to make the most use of larger vessels; perhaps in future if these vessels are sold or scrapped or simply find more employment due to a buoyant market then smaller vessels may be used again. By that time it may be too late to alter the new port geography that has developed from an extended period during which small vessels are laid up or scrapped. Second-tier regional hubs may already have inserted themselves in these flows.

Figure 6 shows the year of entering service for the vessels in the sample. The figure shows that by far the majority of sub-1,000 TEU vessels in service are in the larger category, even more so when considering those recently built, as all vessels still in operation that were built prior to 1982 are 0-499 TEU. Therefore, the average age of 0-499 TEU vessels is 20 years and for 500-999 TEU vessels it is 14 years, with a combined average of 15 years. Many of these vessels, particularly in the sub-500 TEU range, are nearing the end of their lives, meaning that they will be phased out soon. As so many are also laid up and almost none being ordered, this suggests that in a few years' time such vessels will be rare indeed, raising questions for the future of those container ports currently relying on them.

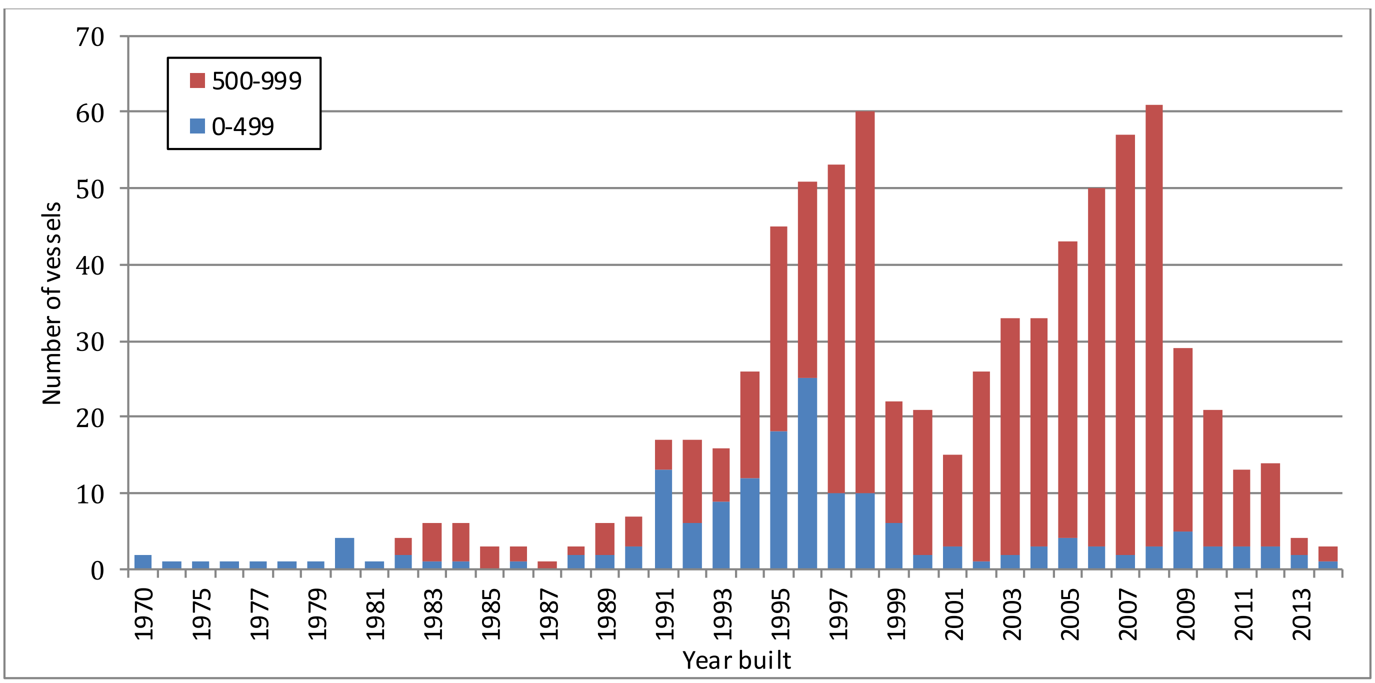

Figure 6 - Year of build for sub-1,000 TEU fleet

5.4 Geographical analysis of "at risk" ports

Section 5.1 revealed that there are 436 ports being served by sub-1,000 TEU container vessels. Of these 436 ports, 90 (or 21% of 420 confirmed data points) have berth depth less than 9.1m. Section 5.2 showed that berth depth of 8.7m is the average cut-off for vessels of 1,000 TEU, and that is using the design draft rather than the full depth required for a heavily laden vessel. Section 5.3 showed that the existing sub-1,000 TEU vessel supply is under threat, with many already laid up, many operating vessels approaching the scrapyard and very few new ones on order. This suggests that, as already inferred from the cascading on larger routes, sub-1,000 TEU vessels are likely to be replaced, at least to some degree, by larger vessels. This section will combine the above results in order to identify and then analyse a sample of "at risk" ports if minimum vessel size increased. As mentioned earlier, it is a difficult dataset to analyse, partly because depth figures are given differently in different sources, and channel depth may not always be restrictive depending on tidal variations. For this analysis the decision was made to include all ports with berth depth below 9.1m and/or channel depth below 7.6m. Some ports had to be removed from the set because of unreliable data, which resulted in a final list of 79 ports for geographical analysis.

The geographical spread is shown in the world map in Figure 7, revealing that the majority are in Europe (35) and Asia (24). While there are no ports in this set from North America and only a handful from Central and South America, that is related to their smaller number of total ports. Europe and Asia combined represent 72% of the 436 ports served by sub-1,000 TEU container vessels and a comparable 75% of the 79 ports in this set. This demonstrates the extensive coastal and island geography of these continents compared to North and South America which have fewer, larger ports.

Figure 7 - World map of small container ports

The geographical analysis required a visual inspection of Google Earth, port websites and secondary data websites (as used for the port and vessel data) for each port to identify where the container terminal was located. Sometimes there is only one port terminal facility and in other cases there may be several installations around an estuary and further upriver. Large islands have not been classified separately, which would not be useful as they are effectively land masses of sufficient size not to be determined by their island status (e.g. large islands such as Great Britain, Ireland, Borneo and island groups linked by bridges, e.g. Japan). Some large islands have several ports, and in many cases the ports may be upriver or estuarial, therefore it was more important to capture these accessibility attributes in the analysis rather than classifying them as islands. Therefore the ports have been segmented into four groups. The first three classifications are coastal, estuary and river locations, as these are the defining features in terms of port access, regardless of whether they are located on islands. The fourth type is small island ports. Of the 79 ports analysed here, 29 are coastal, 22 estuarial, 17 upstream river ports and 11 are small islands.

Figure 8 charts the relation between geographical region and port location. A full list of all small ports including location and vessel calls is provided in Table 4 in the appendix. Findings reveal the high proportion of estuary and river ports in both Europe and Asia, but with more river ports in Europe and more estuary ports in Asia. This reflects the geography of larger navigable rivers in Europe and the common occurrence of deltas and estuarial locations in Asia but rivers becoming less navigable upstream.

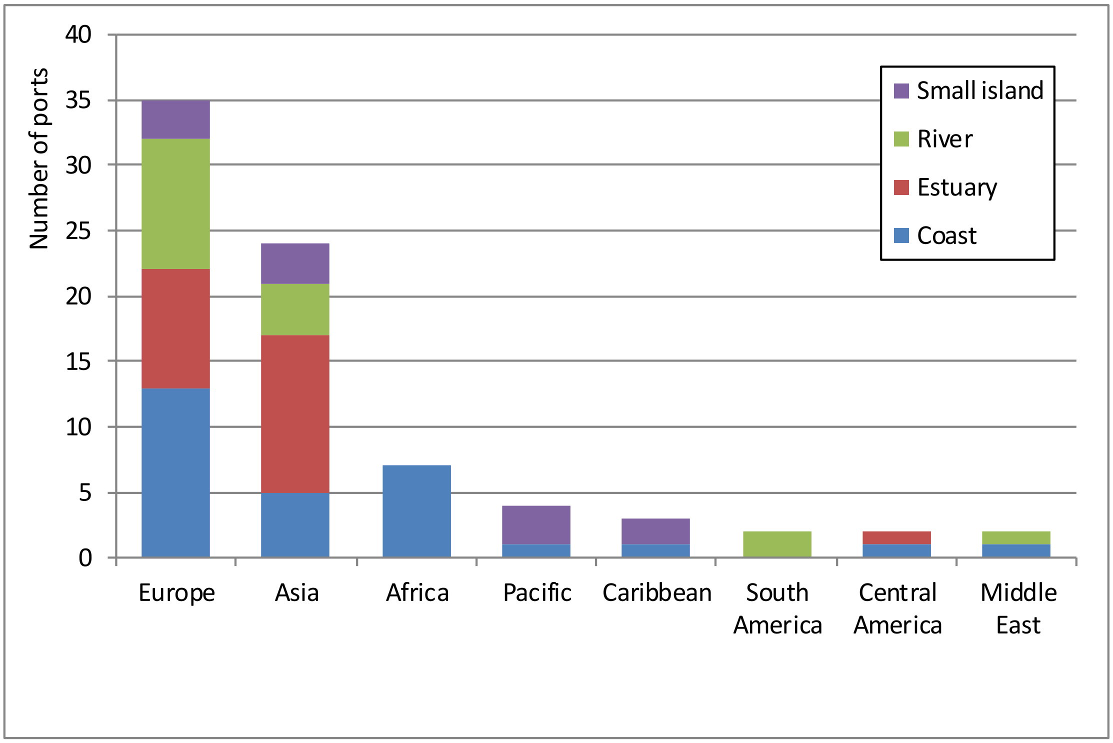

Figure 8 - Geographical region cross-referenced with location

Ports with poor landside accessibility cannot be served overland from a competing port in the same range, but even though they should then continue to be served, they may incur an additional cost (see next section) for an operator to utilize less profitable smaller vessels or transship at a secondary hub from large to small feeder. While a full analysis of the possibilities for second-tier hubs lies beyond the scope of this paper, the key opportunities for such concentration can be identified from the world map in Figure 7, which reveals that a cluster of such small ports may be identified in several locations, notably Southeast Asia, Japan, the Irish Sea and the (East and West) Baltic Sea.

Detailed range-by-range analysis will be required to consider the future of those ports with potential second-tier hubs nearby. In any such range there will be more than one port that could potentially be rivals for these small ports but it depends on many factors as elaborated in the analysis in the following section. Future research is needed to analyse a specific range and identify the small ports at risk and those medium or large ports that could compete for their cargo, undertaking close analysis of their demand profiles and network connections and modelling different service configurations with various fleet profiles. An interesting piece of future research would be to select two ranges in different geographical contexts for comparison.

The next step is to analyse the range of vessels calling at the ports. The full list is provided in Table 4 in the appendix. Figure 9 shows that, while the percentage split of vessel sizes is reasonably similar across the estuary, coast and river port types, the main difference is that estuary ports show a smaller share of 500-999 TEU, replaced by a larger percentage of vessels over 1,000 TEU. It also shows that, besides the split of 0-499 TEU and 500-999 TEU already discussed in previous sections, 20 per cent of calls at these ports were by vessels over that threshold (although a third of these were at one port – Yangon). This raises an interesting point with regard to such vessels. While of course vessels of capacity 1,000-1,500 TEU exist that have sufficiently shallow design drafts to berth at some small ports, they have deeper depth requirements when laden towards this threshold. Every one of the larger vessels in this dataset has a full laden depth requirement beyond what any of these ports should be able to accommodate, which reveals that they were far from fully loaded. Thus the appearance of such vessels in the dataset does not mean that they offloaded any more containers than the smaller vessels, which is not an efficient use of vessels in the long term. In fact, it suggests that such vessels are already being cascaded even when they are underutilized, and if they are going to be utilized towards their capacity potential then ports will need to deepen their berths. Furthermore, as discussed in the next section, even if a port does upgrade to accommodate larger vessels, it will mean fewer calls which puts other strains on the system.

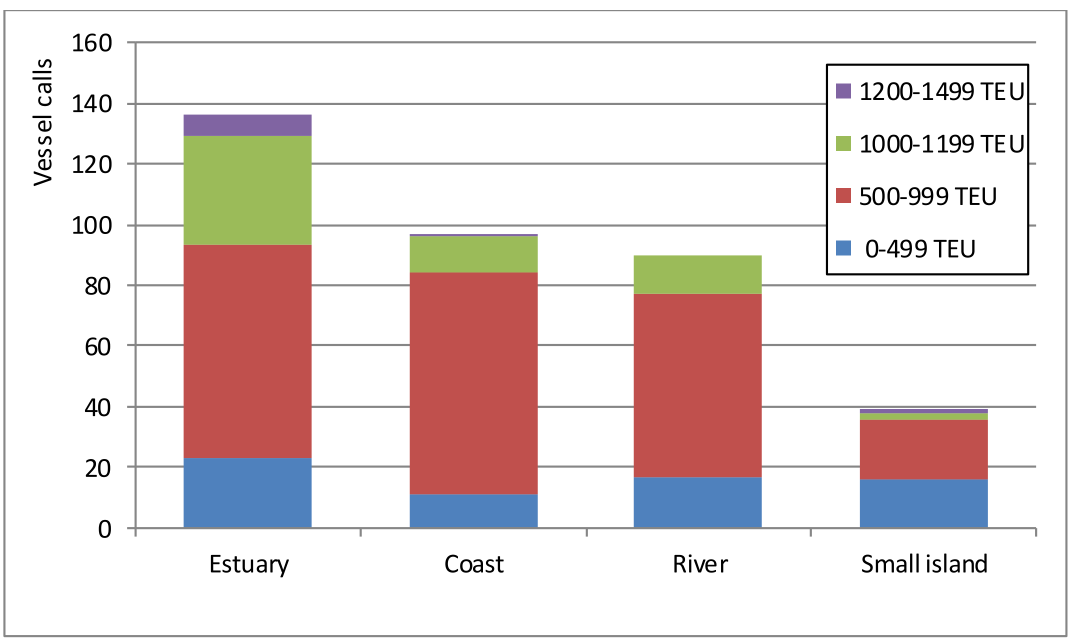

Figure 9 - Vessel call per size range and port location

The analysis in this section has revealed that a handful of countries have a significant number of ports with depth restrictions that will be severely challenged as vessel draft increases. The likely responses by carriers and the strategies available to port stakeholders will be considered in the following section.

6. Strategic responses by ports at risk

The question for discussion is what strategies will result from the situation identified in the preceding analysis. If a small port is currently served by 1,000 TEU vessels from transhipment hubs and shipping lines decide to scrap such vessels and replace them with larger ones, a few potential scenarios may result. The first and most obvious strategy is that the small ports may upgrade to handle larger vessels. This may require large investments to dredge berths and access channels, as well as lengthening berths if necessary, in addition to upgrading the handling capacity through larger cranes, yard redesign and improved processes at the gate and access infrastructure. There are several impediments to this course of action, besides the simple fact of the cost. Many of these ports (although by no means all, as shown in section 5.4) are from countries with less effective governance regimes in place to develop the ports, especially as they will in most cases be publicly owned and therefore may find it difficult to justify large expenses for port expansion. Large international operators may take them on (or may already run them) if the price of expansion work is factored into their concession arrangement. But they could just as easily operate a different port where such constraints do not exist.

Even if the port upgrades, there will be fewer calls. Ceteris paribus, doubling the vessel size would halve the number of calls, although in reality the reduction would probably not go as far as that. Recent research has identified cases where larger vessels have been cascaded down to routes where their capacity remains underutilised. This may lead to two main problems. First, many smaller ports only have a handful of container vessel calls per week. Is it viable to remain open for fewer calls? Second, less frequent calls will place limitations on the supply chains of local shippers, leading to increased costs for example through the need to increase inventories, depending on individual requirements. They will either have to absorb this cost or find an alternative route, through a different port and then overland.

If the port does not upgrade and consequently cannot accommodate the new vessels, it will lose traffic to the nearest port in the area large enough, who will then serve the market by overland links. This will result in increased costs for local shippers. It was already reported in 2016 that Maersk was withdrawing services to several small feeder ports in China (Shen, 2016).

Finally, if no sufficiently large ports exist in the area or overland links are not available or sufficient, then traffic must continue to use this port. In this case it will go via a second-tier hub and be feedered there on small vessels. There is even the remote possibility that such small vessels will disappear entirely so this option may not even exist. Increased costs caused by rising oil prices (until recently) and the increased price of low-sulphur fuel (needed for SECA regulations – research suggests that owners are not going to make investments in these old vessels and will either scrap them or use low sulphur fuel) are strong drivers for shipping lines to operate larger vessels, in order to spread any cost increases across more containers. Any of these strategies will result in a large cost increase for users of maritime transport.

The likely reality is a combination of the above strategies at different ports across the globe. In order to systematise the findings from the preceding analysis, Hayuth's (1981) list of factors for the development of a load centre port can now be applied. These factors are generally applied to large ports but they can be reinterpreted in relation to small ports, based on the findings in this paper. Hayuth identified five major influences:

A large-scale local market: Even if the scale of local markets is sufficient in totality, it may require regular small container drops rather than large ones. Given the rise of just-in-time logistics and lean and agile supply chains, many firms are no longer able to store large inventories and rely on regular small deliveries.

High accessibility to inland markets: large container drops may also challenge the connecting infrastructure if the region is used to lower port traffic. Road congestion may result, and rail lines (if available) may not have capacity for longer or more frequent trains, and rail operators may have difficulty balancing flows, depending on the import/export balance of the region.

Advantageous site and location: a once-advantageous site becomes less so due to physical limitations as greater draft is required than once was. Also relating back to the first point about the scale of the market, a more intermediate location may be required in order to consolidate and store goods as modern supply chains are built around regular small deliveries rather than fewer large goods movements. So an intermediate port location with land available for logistics may be suitable. This may explain to some degree why some ports advocating their market offer of port-centric logistics tend to be secondary ports with available brownfield land from departing industrial activity (Monios & Wilmsmeier, 2012b).

Early adoption of the new system: due to the time-lagged nature of large infra- and superstructure investments, if one smaller port takes the first mover advantage and expands port capacity, it may succeed at the expense of others. This factor applies even more so if the port develops logistics initiatives to store cargo, or offers increased facilities such as container freight stations and empty depots to provide shippers with increased flexibility and choice with regard to cargo storage, sorting and postponement.

Aggressiveness of port management: small ports tend to be less aggressive as they rely on the captive local market rather than fierce port competition that is the norm for larger ports competing for overlapping hinterlands. Small ports may find it difficult to obtain investment from public sector sources who may view expansion as speculative or unnecessary, while private investors are less interested in such a small port. If they are interested in such ports, it is more likely because they are attracted by the regular returns from that captive market (Baird, 2013), in which case they are even less likely to invest in expansion. Looking from the other end of the spectrum, large ports with congestion problems are less interested to handle small vessels as they attract less revenue, so aggressive management from large ports will reduce the likelihood of small feeders calling there, further driving the adoption of larger feeders.

In the past, as long as a port was able to handle container vessels up to around 500-1,000 TEU then it made sense for the vessel to visit each port of this type rather than concentrate flows in a local hub. However, a consideration of Hayuth's five drivers for a load centre port indicates that, just as container ports at the larger end of the scale were rationalised as flows concentrated at a handful of major hubs, several drivers exist for the same process to be observed at small ports. Rationalisation of vessel calls at smaller ports can be expected; in response, some ports will expand to handle larger vessels and some will inevitably disappear from feeder schedules.

The final step in this discussion is to reflect on how the geography of small container ports as elaborated in this paper will influence the strategies available to port stakeholders. Coastal ports with competitors in the same range are more at risk of losing their trade to another port and being served overland from there, whereas more geographically isolated ports may not be able to be served overland. This is most obviously the case for small islands or even larger islands where the small container port is the only available option. Usually in such cases demand for containerized transport is insufficient to support two competing facilities, and in many cases formerly small port authorities have already been merged (e.g. Reykjavik, Iceland). Similarly, many estuary ports and particularly upstream river ports in poorly accessible locations have relatively captive local markets, therefore shipping lines will continue to serve them, but inevitably prices will rise if carriers need to put on a special service using a less economic smaller vessel, or if the ports need to invest in berth and channel dredging. Moreover, even some coastal ports occupy inaccessible locations surrounded by jungle and mountainous terrain (e.g. several in Indonesia), making them effectively island locations that will continue to be served. Considering the geography of port system evolution, the question raised by these findings is whether opportunities exist within such regions for a port to emerge as a second-tier hub, concentrating flows from larger vessels and using small feeders to serve these small isolated ports.

7. Conclusion and research agenda

This paper has looked specifically at the supply-side influences on port systems and the findings are subject to the data limitations discussed above. Additional analysis could be conducted from a longitudinal quantitative perspective as well as a qualitative approach involving case studies of individual ports to understand how they are facing this challenge, which will relate in some cases to issues of governance and stakeholder management. In many cases the decision on infrastructure expansion will rest with public bodies such as cities, often the major or sole shareholder of such port authorities, but investment commitment is not easy to achieve in the current economic climate.

Future research could cross-reference location and distance to generate clusters of draft-restricted feeder ports within specific port ranges in order to explore whether ports in the same system would be able to accommodate these vessels, and then to consider the impact on the port range or system in particular geographical locations. By identifying the likely winners of such rationalisation, the ports may be identified that will be attractive to private port operators, since investing there will bring fairly secure rewards because traffic is less footloose (as it often is in ranges where large ports compete for an overlapping hinterland). Therefore, making a small investment to upgrade one of these ports could be more attractive than investing huge sums expanding a large port but still losing traffic to a competitor. Therefore small ports can, in the right circumstances, mean small investment, secure traffic and good profit.

Other factors not considered in this paper will influence the demand for container shipping and therefore to some degree the supply, not only in total capacity but the structure of services and the kinds of vessels required. For example, access to energy (e.g. oil prices, LNG infrastructure), new technologies like 3D printing that may reduce the need for shipping or changing supply chains as a result of some reshoring of production back to developed countries. Any or all of these factors may drive greater rationalisation of services and further pursuit of economies of scale through ever-larger vessels. Alternatively, they may encourage greater atomisation and less demand for such ultra-large vessels on the major trade lanes.

The final results of such trends cannot be predicted in advance. Yet the findings from this paper suggest that a greater rationalisation of smaller ports can be expected, with some expanding to handle larger vessels and some disappearing from feeder schedules. Whether shippers currently utilising such ports will then be served overland or by smaller feeders or not at all will be the next question. Policy makers and planners supporting such shippers will need to consider how they can best serve them, by upgrading ports, upgrading connecting infrastructure to neighbouring ports, being prepared to subsidise their increasing transport costs or lose competitiveness to other shippers. The penalty of peripherality, already suffered by many producers and consumers not located on the main trade lanes, may soon grow worse.

What this means for the geography of port system evolution is that second-tier hubs identified in the literature are likely to continue to emerge, driven by some of the trends identified in this paper. The future analysis mentioned above of individual port ranges will be needed to identify the changing role of medium-sized or secondary ports. These are mostly feeder ports but of sufficient traffic demand and infrastructure capacity to attract some direct flows. These ports usually do not have the natural competitive advantages (e.g. location) that in many cases explain the success of the dominant ports in each range. Thus, they often fight aggressively to improve their status and attract more direct links from their larger competitors through a variety of management and investment strategies. Future research, building on this paper, should investigate this emergent phenomenon of secondary ports attracting sufficient flows that are either taken from small ports and their shippers served overland or else the flows are feedered to the smaller ports, turning the secondary ports into second-tier hubs for a smaller scale hub-and-spoke system. The underlying question is to determine whether this is a transitional process of port competition or a more permanent change, representing a distinct stage in the evolution of port systems.

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Appendix

Table 3 – List by country of containers ports served by sub-1,000 TEU vessels

Country	Ports	Country	Ports	Country	Ports
Japan	43	Ukraine	3	Guyana	1
China	37	Bahamas	2	Honduras	1
Indonesia	22	Croatia	2	Ivory Coast	1
Spain	20	Dominican Republic	2	Jamaica	1
UK	17	Egypt	2	Jordan	1
Italy	15	Equatorial Guinea	2	Kenya	1
Russia	13	Estonia	2	Kiribati	1
Norway	12	Fiji	2	Kuwait	1
South Korea	11	Guatemala	2	Latvia	1
Sweden	10	Haiti	2	Lebanon	1
Turkey	10	Iceland	2	Lithuania	1
France	9	Israel	2	Madagascar	1
India	9	Mauritania	2	Malta	1
Malaysia	9	Poland	2	Marshall Islands	1
USA	7	Qatar	2	Mayotte	1
Algeria	6	UAE	2	Mexico	1
Ireland	5	Vanuatu	2	Myanmar	1
Portugal	5	American Samoa	1	Netherlands	1
Taiwan	5	Argentina	1	Netherlands Antilles	1
Vietnam	5	Aruba	1	Nicaragua	1
Australia	4	Bahrain	1	Oman	1
Brazil	4	Bangladesh	1	Puerto Rico	1
Greece	4	Barbados	1	Romania	1
Libya	4	Belize	1	Saudi Arabia	1
Morocco	4	Bulgaria	1	Singapore	1
Netherlands	4	Cambodia	1	Slovenia	1
Papua New Guinea	4	Canada	1	Solomon Islands	1
Philippines	4	Costa Rica	1	Somalia	1
Venezuela	4	Cuba	1	Sri Lanka	1
Belgium	3	Curacao	1	Sulawesi	1
Chile	3	Cyprus	1	Suriname	1
Colombia	3	Ecuador	1	Syria	1
Denmark	3	El Salvador	1	Tanzania	1
Finland	3	Faroe Islands	1	Thailand	1
Germany	3	French Polynesia	1	Togo	1
Iran	3	Gabon	1	Tonga	1
New Zealand	3	Gambia	1	Tuvalu	1
Panama	3	Georgia	1	Uruguay	1
Trinidad and Tobago	3	Greenland	1	Yemen	1
Tunisia	3	Grenada	1	**Total**	**436**

Table 4 - Full list of small container ports with location and vessel calls

Region	Country	Port	Location	0-499	500-999	1000-1199	1200-1499	Total
Europe	Belgium	Ruisbroek	River	1				1
Europe	Croatia	Split	Estuary		1			1
Europe	Estonia	Kunda	Coast		1			1
Europe	Finland	Mantyluoto	Coast		3			3
Europe	France	Port Vendres	Coast		2			2
Europe	Germany	Lubeck	River		1			1
Europe	Greece	Suda Bay	Estuary		1			1
Europe	Iceland	Reykjavik	Estuary		8		4	12
Europe	Ireland	Drogheda	River	1				1
Europe	Ireland	Waterford	River		2			2
Europe	Italy	Ortona	Coast	1				1
Europe	Italy	Savona	Coast		3			3
Europe	Netherlands	Moerdijk	River	3	10			13
Europe	Netherlands	Terneuzen	River		1			1
Europe	Norway	Borg Harbour	Estuary		2			2
Europe	Norway	Drammen	River		8			8
Europe	Norway	Floro	Estuary		1			1
Europe	Poland	Szczecin	River		7	2		9
Europe	Portugal	Figueira da Foz	Coast		2			2
Europe	Russia	Korsakov	Small island	7				7
Europe	Russia	Kronshtadt	Small island		11			11
Europe	Russia	Vyborg	Estuary		1			1
Europe	Russia	Yeisk	Coast	1				1
Europe	Spain	Arrecife	Small island		4			4
Europe	Spain	Bermeo	Coast		1			1
Europe	Spain	Melilla	Coast		3			3
Europe	Spain	Seville	River		1			1
Europe	Sweden	Ahus	Coast		2			2
Europe	Sweden	Halmstad	Coast		1	2	1	4
Europe	Sweden	Malmo	Coast		2			2
Europe	Sweden	Sodertalje	River		3			3
Europe	UK	Belfast	Estuary	1	11			12
Europe	UK	Grangemouth	Estuary		9	1		10
Europe	UK	Kirkcaldy	Estuary		1			1

Europe	Ukraine	Berdiansk	Coast	1	1			2
Asia	India	Haldia	Estuary		3	3	2	8
Asia	India	Kakinada	Coast		2			2
Asia	India	Kolkata	River		14	8		22
Asia	Indonesia	Amamapare	Estuary		2			2
Asia	Indonesia	Balikpapan	Estuary	3	3			6
Asia	Indonesia	Banjarmasin	River	6	6			12
Asia	Indonesia	Batu Ampar	Small island	3				3
Asia	Indonesia	Baubau	Small island	1				1
Asia	Indonesia	Kota Baru	Estuary	1				1
Asia	Indonesia	Pontianak	River	1	4			5
Asia	Indonesia	Sampit	River	1				1
Asia	Indonesia	Teluk Bayur	Coast	4	1			5
Asia	Japan	Imabari	Estuary	4				4
Asia	Japan	Imari	Estuary	2	3			5
Asia	Japan	Kanazawa	Coast	2	3	1		6
Asia	Japan	Yatsushiro	Estuary	2				2
Asia	Malaysia	Kuching	Estuary	6	7	6		19
Asia	Malaysia	Labuan	Small island		3			3
Asia	Malaysia	Sandakan	Estuary		1	1		2
Asia	Malaysia	Tawau	Estuary		1	2		3
Asia	Myanmar	Yangon	Estuary		13	21	1	35
Asia	Papua New Guinea	Kavieng	Coast		1			1
Asia	South Korea	Gyeongin	Estuary	2				2
Asia	Thailand	Songkhla	Coast		12	6		18
Africa	Algeria	Annaba	Coast	1	2	2		5
Africa	Algeria	Ghazaouet	Coast		1			1
Africa	Libya	Tobruk	Coast		2			2
Africa	Mauritania	Nouadhibou	Coast		1			1
Africa	Morocco	Dakhla	Coast		1			1
Africa	Morocco	Tan Tan	Coast	1				1
Africa	Tunisia	Bizerta	Coast		2			2
Pacific	Kiribati	Tarawa Atoll	Small island	1				1
Pacific	New Zealand	Nelson	Coast		1			1
Pacific	Solomon Islands	Noro	Small island		1	1		2
Pacific	Tuvalu	Funafuti	Small island	1				1
Caribbean	Bahamas	Nassau	Small island	3				3

Caribbean	Dominican Republic	Puerto Plata	Coast		1			1
Caribbean	Grenada	Grenada	Small island		1	1	1	3
South America	Chile	Punta Arenas	River		2			2
South America	Suriname	Paramaribo	River		1	3		4
Middle East	Iran	Khorramshahr	River	4				4
Middle East	UAE	Ajman	Coast		1			1
Central America	Guatemala	Santo Tomas de Castilla	Coast		21	1		22
Central America	Guyana	Georgetown	Estuary	2	2	2		6
			Total	**67**	**223**	**63**	**9**	**362**