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Abstract: Much of the success of containerisation is due to time economies, particularly the reduction in the duration of port calls. Although vessels now spend a small amount of time in port compared with the time at sea, it is still a cost factor. The focus of this study is the amount of time container vessels spend in port. The average vessel turnaround times (ATTs) involving 70 ports of call involved in four major trade routes are examined. The principal research questions addressed are: how do ATTs vary among ports and how is this time metric related to port performance? ATTs are compared with traffic volumes measures of port efficiency. The results are weak and lead to a hypothesis that ATTs are differentiated regionally and functionally, rather than globally. Evidence is presented for this hypothesis. Several theoretical issues are considered arising from the results and questions for further research are presented.

Keywords: container shipping; ports; ship turnaround times; port efficiency; regional differences.

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1 Introduction

Much of the success of containerisation is due to time economies, in particular the way in which the length of time ships spend in port has been reduced. In case of the former general cargo trades ships would spend many days or weeks in port compared to a few hours for a modern container vessel, thereby permitting shipping lines to undertake more revenue-generating voyages per vessel per year. Although vessels now spend a small amount of time in port compared with the time at sea, it is still a cost factor, and minimising terminal costs is an objective of service design by the carriers. In addition, delays in ports caused by congestion, strikes or other dislocations result in carriers skipping ports or levying congestion surcharges. Shippers, too, have expressed concerns about the schedule unreliability of container shipping (Notteboom, 2006; Vernimmen et al., 2007) suggesting that time remains an operational and competitive factor.

Despite its importance, consideration of the time ships spend in port has been difficult to analyse in detail. A particular problem has been that of measuring time at sea and in ports, with the only widely available metric being the carriers' published schedules and voyage itineraries for the time at sea. Actual time metrics from individual ports (port time) and shipping lines (at sea) have been difficult to obtain because of confidentiality. This has been resolved recently with the availability of global geographic positioning of ships, which track all ship movements in real time.

The focus of this study is on the length of time ships spend in port. The average vessel turnaround times (ATTs) for a base set of ports involved in a number of major container trades are obtained. A large database was compiled containing measurements based on actual port times rather than estimates or values drawn from service schedules. This provides an important research tool. Time delays in ports have been seen as indicators of congestion and/or poor productivity, and superior time performance has been identified as a factor in port competiveness and efficiency (Peters, 2001; Zhang et al., 2014), but the lack of actual time measurements have made it impossible to fully test this. Speed of vessel turnarounds is seen as a critical factor for transhipment. The data compiled here provides an opportunity to test the relationships between port time and port efficiency. The principal research question addressed here is: how do ATTs vary among ports and how this time metric is related to port performance. One important hypothesis drawn from the academic literature is tested: that transhipment hub achieve faster vessel turnarounds than other ports.

Following this introduction the paper is organised in four sections. First, an extensive literature review is undertaken to assess how time has been considered in previous academic studies. A wide set of approaches is revealed but these diverse studies confirm the importance of time as a factor in determining performance and competitiveness. On the other hand, the lack of precise measurements of ships time is identified as a serious constraint. Second, a section is presented that deals with methodology, and describes the source of data employed in this research and how it is organised. The data set represents a large sample comprising 17,024 port calls, involving 70 ports of call. Third, is a section that seeks to explain differences in ATTs with factors such as numbers of containers handled and port efficiency. The results lead to a second, more detailed, examination of ATT scores and to the proposition that ATTs are differentiated regionally and functionally, rather than globally. Evidence is presented for this hypothesis. The fourth section is the conclusion in which the findings and their implications are summarised. Directions for further research are presented.

2 Literature review of time in container shipping

The role of time in the container shipping scientific literature is assessed under five headings:

1 time in port and carrier choice

2 time in port and terminal efficiency

3 time in port benchmarking

4 time in port operations research

5 new sources of time data.

2.1 Time in port and carrier choice

One of the longest research threads has been that of port and carrier selection criteria. Research in this field extends from the 1980s to the present (Slack, 1985; Brooks, 1993; Malchow and Kanafani, 2001; Song and Yeo, 2004; Tongzon and Sawant, 2007; Chang et al., 2008; Wiegmans et al., 2008; Tongzon, 2009; Grosso and Monteiro, 2009; Saeed and Aaby, 2013). There is considerable diversity represented by these studies: some consider the selection criteria of shippers and third parties (Slack, 1985; Grosso and Monteiro, 2009); others examine the criteria of shipping lines (Wiegmans et al., 2008; Tongzon and Sawant, 2007); some use stated preference surveys (Slack, 1985; Saeed and Aaby, 2013), while others employ revealed preference surveys (Tongzon, 2009); and methods employed vary from descriptive statistics to multivariate methods including Analytical Hierarchical Process (Song and Yeo, 2004), multinomial logit models (Malchow and Kanafani, 2001), and principal components analysis (PCA) (Grosso and Monteiro, 2009).

There are important differences between the studies in terms of results. Those of shippers and third parties reveal the importance of criteria such as port location, number of sailings, port efficiency, while carriers' port preferences favour hinterland connections and accessibility, port tariffs, handling speed and reliability. Brooks (1993) revealed that the ranking of criteria remained relatively stable over time in her case studies. Tongzon and Sawant (2007) indicated that opinions differed among the same group of carriers when revealed preference and stated preference surveys were administered to the same group. The former results placed more emphasis on operational issues such as port charges and port services, whereas tactical concerns such as efficiency and connectivity issues were more important when stated preferences questionnaires were administered. Perhaps the most important difference in the ranking of criteria is where the respondents are located. In North America and Western Europe hinterland accessibility is a particular concern, while in Asia port efficiency emerges as a key factor. These differences reflect the fact that Asian ports are primarily export-oriented while those in Western Europe and North America are more import-based.

Actual measurements of time are rarely stated explicitly in these studies; rather 'time' is an implicit factor in several of the key criteria identified. Thus, the geographic location of the port, frequently selected as a criterion by shippers in these studies, reflect both cost and time of accessing the port, in the same way as hinterland accessibility and connections are identified as key factors for carriers. Where precise measurements of accessibility and proximity are provided they are usually expressed as distance rather than time or cost. Time also appears when port efficiency is considered as a selection criterion, since delays are seen as a manifestation of poor performance. However, in the absence of actual time measurements its importance remains indeterminate.

2.2 Time in port and terminal efficiency

While port efficiency emerges as a factor in many port and carrier surveys, it is also a topic that has generated a considerable range and volume of academic research by itself. Over the last 20 years the application of multivariate techniques such as Data Envelopment Analysis (DEA) (Tongzon, 2001), Stochastic Frontier models (SFA) (Cullinane and Song, 2006) have been used to estimate port efficiencies in case studies around the world. A recent paper (Panayides et al., 2009) has provided an excellent review of the DEA literature and the results. The majority of papers reviewed consider container traffic as the output, although there are some others that consider the number of vessel arrivals as well (Lin and Tseng, 2007). The variables selected as inputs include a range of measures of the physical dimensions of the ports: length of berths, number of cranes, and terminal area among others. Panayides et al. (2009) noted that key time metrics such as crane moves per hour and berth occupancy rates have been omitted, largely because of the difficulty in acquiring such measures. The significance of such time-based metrics was recognised by Tongzon and Heng (2005) in their study of port efficiency:

> "Productivity is a measure of the efficiency of port or terminal operations, and accounts for the amount of resources usually required to perform a given task in a given time. Therefore, the level of efficiency can represent how quickly containers are handled and how quickly vessels are turned around at ports." Tongzon and Heng (2005, p.409)

The lack of time metrics in DEA and SFA studies is therefore a major weakness, which raises questions about the conclusions generated by such research.

Non-DEA or SFA studies of port efficiency have tended to use multiple regression or PCA. Here again, however, the collection of time data has proven to be challenging. For example, while Tongzon and Heng (2005) had noted the importance of such metrics, their PCA analysis of the results of SFA efficiency scores had to exclude the measure of average vessel time in port because of a lack of cooperation from the shipping lines. In a study that used a Tobit regression model that considered overall efficiency measures of US container ports derived from DEA scores as the dependent variable, Turner et al. (2004) included no time-based independent variables. One example of a multivariate analysis that did employ time data is that of Sanchez et al. (2003) in which seven of the nine selected independent variables chosen to represent efficiency were time-based. The data were obtained from a survey sent to 55 ports in South America, from which complete data from 19 respondents were used. It is not surprising therefore that time measures were identified in two of the three factor loadings extracted as a result of varimax rotation of PCA scores: 'time inefficiency' and 'vessel waiting time'.

2.3 Time in port benchmarking

Benchmarking port performance by employing key performance indicators (KPIs) represent an institutional approach to port efficiency and performance. There is a divergence between academic papers on KPIs and those actual programs carried out in particular jurisdictions. The former tend to draw up a very extensive list of indicators to provide as complete picture of port performance as possible. For example when Transport Canada was considering introducing a program of KPIs in the early 2000s for container shipping an academic consultant in a confidential report provided a list of over

50 criteria. The individual port authorities rejected this, complaining over the cost and effort required to collect such data and emphasising that many would give rise to legal problems with the tenants of terminals who would oppose divulging confidential data. Quite different are the benchmarking measures implemented by public agencies which tend to use a relatively small set of criteria. For example, Transport Canada collects 11 metrics on container activities in ports, of which eight involve time factors. For bulk cargoes it collects data on six criteria, three of which are time-based (Comtois and Slack, 2009).

The Australian BITRE (2015) has played a major role in benchmarking. Arising out of government legislation seeking to reform port industry labour in 1989, a mandated reporting of container port performance was undertaken. Indicators are published quarterly for wharf-side productivity and terminal productivity. Six of the seven wharf-side measures involve time, and all of the 11 terminal productivity measures involve a time dimension. The European Seaports Organisation (ESPO), collects and publishes on an annual basis data on port performance for 85 ports of all sizes, that range from dimension characteristics, labour trends, environmental performance, and utilisation measures, as well as service quality measures of which time metrics are dominant (European Seaport Organisation, 2012).

2.4 Time in port operations research

Operations researchers have produced an extensive literature on optimising individual aspects of port operations using mathematical programming and systems analysis. The objectives are to prevent delays and improve efficiency. Recent examples include ship scheduling (Agarwal and Ergun, 2008), berth occupancy (Cordeau et al., 2005; Imai et al., 2008), equipment efficiency and the layout of container yards (Kozan, 2000). These studies are primarily methodological, each one applying a new technique or modifying an established approach, and most typically test the theoretical results to a limited set of case studies. They demonstrate how even small modifications to terminal operations can improve throughputs and hence achieve time economies.

In recent years operations researchers have turned their attention to ocean transit times and the length of port calls. This has arisen because of the emergence of slow steaming in container shipping, where the carriers have lowered average speeds in order to reduce fuel consumption because of the high cost of bunker (Cariou, 2012). The optimal network structure to achieve cost savings with the constraints of transit times and ports of call represent interesting new operational challenges. Reinhardt et al. (2016) estimated the amount of reduction in bunker consumption that can be achieved by a company by simply changing the time of the port calls. The results indicate that some economies are possible (less than 10%), but it is not clear how the penalties for changing the port arrival times might be in reality, since it is known that late arrivals is one of the most important factors in the lack of punctuality in container shipping (Vernimmen et al., 2007). Song et al. (2015) considered the issue of services needing to limit speed but where vessel times in port is the source of uncertainty. They claim that the widely-held assumptions that slow steaming might improve this issue because the vessels can speed up to correct delays are incorrect. They indicate that carriers are reluctant to increase speed beyond certain limits, because of fuel costs. Since port delays are one of the key issues in their study, its measurement becomes critical. Song et al. (2015) employ the scheduled port times and assume variability follows a normal distribution at each port-of-call, and that the maximum port time is equal to five times the minimum port time. Real port times may differ significantly, if only because the actual numbers of containers exchanged per visit vary considerably, but also because the actual variability in port times is definitely unequal, with certain ports achieving consistently higher levels of vessel turnaround performance.

Brouer et al. (2012) considered how to recover schedule efficiency when there are unforeseen disruptions in a service caused by weather, strikes, berth availability, expected congestion. Solutions might include speeding up (thereby using more fuel), skipping a port, and swapping port calls. There is a large literature on responses to airline disruptions, but the conditions of container shipping made such solutions inapplicable because there are so many fewer and slower services between ports than those available to airlines, and passengers are easier to shift from one service to another than is in the case of containers. The paper considers four cases based on actual histories provided by a shipping line. The proposed model was shown to provide acceptable solutions to three of the cases, although the impacts on customers along the chain where vessels skipped a port were not assessed.

2.5 Time in port: new sources of time data

It is only in the last decade that transport specialists have begun to use Lloyds Maritime List Intelligence (LMIU) data. Up until 2008 this data set was based on ships schedules and observations of ships movements recorded by Lloyds' agents around the world. Saldanha et al. (2006, 2009) used this source to calculate transit times between ports to examine differences between carriers and the impact on logistics cost and reliability. Ducruet et al. (2010), Ducruet and Notteboom (2012) and Ducruet and Zaidi (2012) used the same data source to compare transit times for container shipping between for 1,050 ports in the world for 1996 and 2006and analysed the resultant network structures. The LMIU has been augmented by the availability of data from global geographic positioning of ships. Ducruet et al. (2014) extended the earlier data set by adding data for 2010 from the new source, and examined the amount of time ships spend in port.

2.6 Conclusions

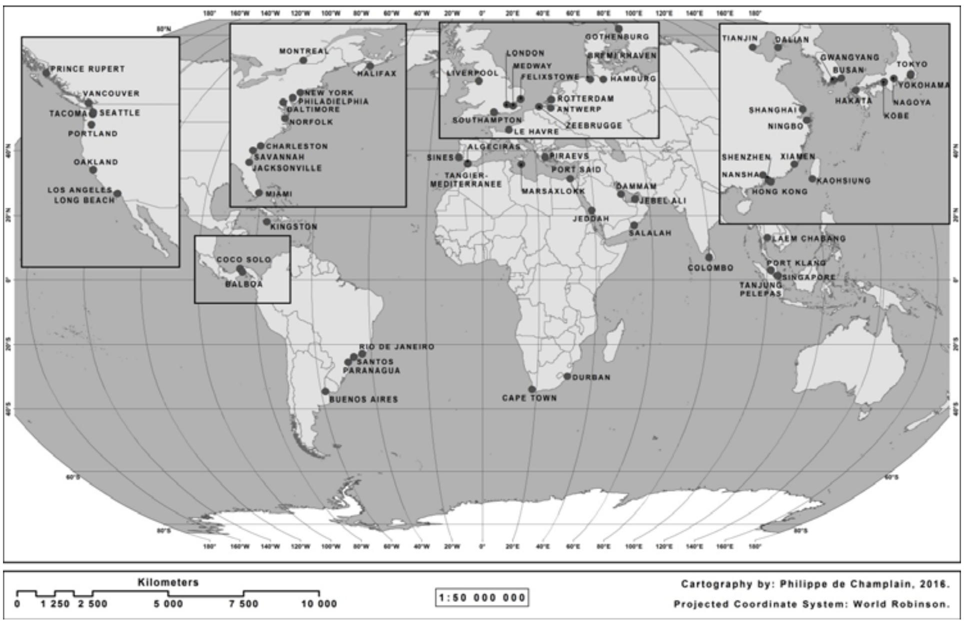
Several conclusions can be drawn from this literature review. First, is that port performance and efficiency have been widely studied, and while the time-related factors have been recognised as important, they has defied a full quantitative consideration. Second, up until quite recently the use of time data has been constrained by data availability and questions of confidentiality. Third, is that benchmarking projects have gone furthest in considering time metrics, but they are of limited spatial coverage (with the exception of ESPO), and temporal extent (except for the Australian case). Fourth, that recent studies using actual reported times of vessel movements have focused on the duration of vessel transits between ports.

This paper considers the duration of vessel turnarounds in ports using real-time data and not estimates. In this way a more precise and realistic appraisal of the time factor can be obtained. Because the focus is on mainline services only, the assessment of the time spent in port is not distorted by regional and feeder container services with their different operational and commercial characteristics. Differences between major ports, and their ability to turn ships around provides a metric that can be compared with other performance indicators.

3 Methodology to analyse ships time in port

The data employed in this study were drawn from Lloyds intelligence unit. This source is considered to be among the most comprehensive of databases on maritime information related to ports, companies and vessels. The database records over four million movements made by the world's merchant fleet every year. The data provides arrival and departure times from terminals for all vessels on most major trade lanes. It is thus possible to determine the amount of time ships spend in port on each port call. It does not indicate whether cargo transfers are occurring during this period. Labour issues such as shift changes and other activities such as bunkering and ship repairs may have taken place as well, but if the ship is at anchor and waiting for a berth these periods are recorded separately. Nevertheless, this metric provides a vastly more accurate indication of time in port than schedule-based data.

Figure 1 Ports included in the present study



Source: Own data

Three major east-west and one north-south trade routes were chosen for analysis: the trans-Pacific, trans-Atlantic, Asia-NW Europe, and NW Europe and east coast of South America. All the weekly services on these trades that included vessel calls at 20 selected ports were recorded: Prince Rupert, Vancouver, Seattle, Tacoma, Long Beach, and Los Angeles; Montreal, Halifax, New York and Norfolk; Busan, Shanghai, Hong Kong, and Singapore; Le Havre, Rotterdam, Hamburg and Antwerp; and Buenos Aires and Santos. These are among the largest ports on each maritime range. Also included are the 50 intermediate ports of call on the services between the 20 selected ports. Services between the intermediate ports and other connections were not recorded (see Figure 1).

The service count comprised vessel movements during a period of four months during 2013 (January, May, September and November). This selection was made to provide a representative sample of annual shipping activity at the 70 ports. It is recognised that the data cover activity for one year only, and that a multi-year survey would provide an even better perspective, but 2013 was a year in which the container trades had recovered from the financial crisis of 2008–2010 and in which conditions overall were as normal as can be found in an industry marked by change. A total of 17,024 records of vessel calls were obtained. From this database the actual times spent in port for each port of call on the services including all intermediate ports of call were calculated. The final step was to calculate mean times and standard deviations for all the ports.

It must be remembered that as large as is the database, it is still a sample. Only the weekly services involving the selected ports are included. The stipulation of a weekly service was to remove many occasional services and those that involved extensive network calls at a very large number of intermediate ports.

Table 1 ATTs, standard deviations and port calls for the 20 base ports

Port	*ATT*	*δ*	*N. calls*
Buenos Aires	36.82	10.52	113
Santos	22.83	9.82	170
Singapore	31.42	21.81	905
Hong Kong	17.24	15.53	1,039
Shanghai	20.43	9.63	1,389
Busan	13.53	8.46	941
Long Beach	66.33	24.22	348
Los Angeles	57.63	26.27	526
Prince Rupert	29.27	15.34	94
Seattle	34.77	15.73	321
Tacoma	38.44	12.47	288
Vancouver)	42.62	19.73	485
Antwerp	29.52	19.99	763
Hamburg	37.69	14.34	827
Le Havre	20.57	13.6	421
Rotterdam	29.7	15.55	1,253
Halifax	18.52	49.22	102
Montreal	59.01	11.17	72
New York	26.08	12.02	284
Norfolk (USA)	13.65	5.91	246

4 Ship turnaround times

The data matrix of 17,024 port calls involving 70 ports reveals that the average vessel stay is 25.53 hours. This indicates a fairly high level of performance overall, and confirm the remarkable improvements in ship turnaround times achieved as a result of containerisation.

There are important differences in the performance of ports, however, and Table 1 reveals that the differences include the number of vessel calls recorded and in the ATT scores for the 20 base ports from which the services were drawn. The latter range between just over half a day to nearly three days, and that variability as measured, by standard deviations, extend from 5.91 hours to 49.22 hours. For the 50 intermediate ports the range is even greater, extending from a minimum ATT of 7.08 hours at Hakata, Japan to 80.76 hours at Durban, South Africa.

Explaining the differences in mean times presents a challenge this paper now addresses. From the literature review two main factors that could explain differences in ATTs are considered: numbers of containers transferred and levels of efficiency at the ports.

4.1 Ships time and numbers of containers transferred

A factor that influences the total time ships spend in port is the number of containers loaded and unloaded at each port call. It can be argued that the greater the number of containers moved across the quay wall will require ships to stay longer in port. This could be tested by comparing ships time with the number of containers lifted during each visit. Unfortunately there are no data available on the actual numbers of containers exchanged at each of the recorded ship calls. The non-availability of these data forced Ducruet et al. (2014) to employ the gross registered tonnage of the vessels as a surrogate. The difficulty with this surrogate is that all the ports on each service string are weighted equally so that when ship capacity is cumulatively added the distortions are likely to be great. Here, two different surrogates are employed: the total container traffic of each port for 2013 and the number of ship calls of each port in the data set. The former is a much broader metric than the ideal because it includes the traffic generated by services not measured in this data set, but at least its activity differentiates between throughputs at different ports. The latter is an indicator both of connectedness with the specific service networks as well as relative activity.

When ATTs are correlated with the annual port traffic for 52 ports for which we have traffic data the resultant correlation $r = -0.03$ indicates no relationship (see Table 2). When ATTs are correlated with number of calls for all 70 ports $r = 0.03$. The lack of association is discussed in Section 4.3.

4.2 Relationship between ATTs and port efficiency

The literature review indicates that port performance can play a role in determining the length of time ships spend in port. More efficient ports may be able to turn ships around faster than others despite high volumes. Thus the lack of relationship between time in port and container throughput could be explained by differential levels of efficiency between ports.

As revealed in the literature review, measuring efficiency is complicated. There are many components including dockside operations, terminal handling, entry gate operations and intermodal connections. Three independent variables employed here, one based on an overall and general score of efficiency, the second with a specific metric of ship loading based on crane use, and the third with the results of a quantitative analysis of the top 20 ports,.

The first measure is the score published by the World Bank which provides a value of the efficiency of port infrastructures that is based on ratings collected by the World Economic Forum. One difficulty is the scores are country-based, so that all ports in a country obtain the same score even when there are many ports located on different maritime ranges. This metric is identified here as WBeff, and two comparisons with ATTs are made (see Table 2). In the first case the efficiency scores are compared with the ATTs of the largest port in in each country. The assumption is that the largest port is the best representative of each country's efficiency rating. This is identified as WBeff1. The second case, WBeff2, uses the actual ATT values of each of the 70 ports in the sample but uses the same country efficiency rating for all the ports in those countries.

Second is a score obtained from the *Journal of Commerce* (2014) that has recently started publishing annual reports on port productivity. It collects data on the number of crane moves per hour. The performance ranking for only the top 20 ports are published, and these ordinal scores are employed here as JOCeff in Table 2.

The third measure of efficiency employs the results of a recent academic study in which efficiency values obtained by DEA for the 20 largest ports in the world (Lu et al., 2015) are identified here as DEAeff. The variables employed to measure efficiency included yard area per berth; the numbers of quay cranes, yard cranes and yard tractors per berth; and, berth length.

Correlations between ATTs and the three indicators of efficiency are presented in Table 2.

Table 2 Correlation between ships time in port and port efficiency measures

	n	*r*
Traffic (total container traffic at ports in 2013)	52	–0.03
Ship calls (number of ship calls at each of ports in the study)	70	0.03
WBeff1 (port infrastructure rating and the traffic of the largest port)	30	–0.03
WBeff2 (port infrastructure rating applied to all ports in each country)	70	0.005
JOCeff (port efficiency measured by crane moves per hour)	20	0.17_{rho}
DEAeff (DEA scores from Lu et al. (2015)	18	–0.15

We suggest that the lack of associations between ATT and independent variables may be due in part to limitations of the independent variables themselves:

- The Traffic variable includes containers that are involved in all shipping services calling at the ports, only some of them are counted here.
- WBeff1 and 2 are based on a rating of port efficiency made by business leaders and are therefore based on perceptions, and all the ports in countries are scored equally. Yet significant differences in ATTs between ports in the same country are revealed in Table 1. Thus, in the US ATTs vary from 13.65 hrs to 66.33 hrs. Rating

differences between countries may be questioned too, with the USA receiving the same score as Namibia.

- Regarding the JOC scores, without more detailed explanations of the methodology, their values may be questioned. For example the port of Long Beach is included in the list of the top 20 ports worldwide in the JOC efficiency rankings, yet it has suffered chronic congestion since 2013 and it scored worst in the ATT results for USA ports.It would be useful, for example, to consider the number of cranes used to work each ship since this can affect ATTs and levels of port performance. Unfortunately there are no such systematic counts available.
- The DEAeff score is drawn from 2009 data at the height of the last recession. While it includes severable variables related to berth and yard operations there are no indications of gate activity and intermodal connections

Given the questions over appropriateness of the efficiency variables, a fourth approach was undertaken involving a multiple regression analysis using the independent variables commonly used in DEA and SFA analyses, such as berth length, water depths and numbers of quayside cranes, along with TEU totals and numbers of vessel calls. Because of the difficulty of obtaining values for all 70 ports, only the 20 base ports of origin were considered. The results of the coefficients are displayed in Table 3. The ANOVA score F = 0.535, with significance 0.747 indicates that the results are not statistically significant.

Table 3 Multiple regression analysis for ATTs of the 20 base ports

Parameter	*Estimator*	*Standard error*	*t-value*	*Significance*
Constant	61.643	33.213	1.856	.085
Berth length	0.000	0.001	–0.041	0.085
Water depth	–1.884	2.363	–0.789	0.945
No. of gantries	0.129	0.221	0.585	0.568
TEU totals	–0.727	0.981	–0.741	0.471
Vessel calls	0.000	0.023	–0.013	0.990
Adjusted R2	–0.140			

4.3 The regional differentiation of ATTs

There is recognition in the ports industry that performance varies regionally. If the ATTs are examined in detail it may be observed that the scores too exhibit certain regional characteristics. It may be noted that ports of different sizes and infrastructure endowments located in the same maritime range possess similar ATTs. Thus, when attempts are made to compare ATTs systematically across the world the results are not significant. In Table 4, the ATTs of 70 ports located in nine maritime ranges are presented.

Table 4 ATTs in regional port groups

Port region	*Number of ports*	*ATT (in hours)*
Central and S. America	7	23.5
South and South-East Asia	6	26.5
East and North Asia	16	17.2
Gulf and Red Sea	4	26.8
Mediterranean	6	20.3
North-West Europe	12	29.5
East coast N. America	10	21.1
West coast N. America	8	46.2
South Africa	2	64.6
Global	70	25.5

Table 5 ATT scores (in hours) for ports on four maritime ranges

N and E Pacific	*ATTs*	*WCNA*	*ATTs*	*ECNA*	*ATTs*	*NWEur*	*ATTs*
Busan	13.53	Long Beach	66.33	Halifax	18.52	Antwerp	29.52
Dalian	17.93	Los Angeles	57.63	Montreal	59.01	Bremerhaven	24.75
Gwangyang	13.95	Oakland	18.81	Baltimore	18.90	Hamburg	37.69
Hong Kong	17.24	Portland	43.01	Charleston	13.68	Le Havre	20.57
Kaohsiung	14.51	Prince Rupert	29.27	Jacksonville	10.89	Rotterdam	29.70
Nansha	78.80	Seattle	34.77	Miami	13.44	Zeebrugge	29.66
Ningbo	13.25	Tacoma	38.44	New York	26.08	Gothenburg	20.08
Shanghai	20.43	Vancouver	42.62	Norfolk	13.65	Felixstowe	30.52
Shenzhen	17.42			Philadelphia	9.20	Liverpool	18.43
Xiamen	14.51			Savannah	16.24	Southampton	29.18
Tianjin	25.28					Medway	16.56
Hakata	7.08					London	29.52
Kobe	10.83						
Nagoya	11.01						
Tokyo	11.43						
Yokohama	9.62						

The results confirm some expected features: that the ports in East and North Asia produce fast vessel turnarounds, despite significant differences in cargo throughputs between ports of Japan and China, and that the west coast of North American ports have some of the longest ATTs. More surprising are the size differences among ATTs between ports on the east coast of North America and those on the west coast. In addition, the east coast of North America ATTs are somewhat shorter than those of the ports of North West Europe, which are slightly higher than the global average.

In Table 5, the detailed ATT scores for ports on these four ranges are displayed. They exhibit a degree of consistency, with the few exceptions being explainable. In the case of North and East Asia (N and E Asia) only Nansha recorded much higher ATT scores than others. Several calls in 2013 involved port stays of up to a week in duration, suggesting a need for vessel repairs. On the west coast of North America (WCNA), Oakland is the only port with an ATT less than the global average. That port serves as a specific function different than all other west coast ports, with its traffic being dominated by exports, particularly empty containers. On the east coast of North America (ECNA) individual port ATTs are at or below the global average, except for Montreal, which is a special case as a niche port where all containers arriving and departing by ship are transferred because it is the only port of call on the services. In the case of North-West Europe (NWEur) the port scores are fairly consistent: just above the global ATT average for the larger ports, and just below average for the smaller ports.

We suggest that these regional differences reflect the basic economic inputs of land, labour and capital that produce distortions in a global analysis. The different combinations of these inputs between East and North Asia, Western Europe, North America and the east coast of North America are very marked, and these make it difficult to forge generalisations at a global level.

Ports in East and North Asia have experienced exceptional growth levels over the last 20 years. The ports themselves are essentially new constructs, occupying new sites that have been developed to respond to this growth. The result is that Chinese and Korean ports are the most modern in the world, occupying new sites (land) and equipped with the latest equipment (Capital). In Europe there are some new terminals that are coming on-stream that are comparable to those in Asia, but most ports occupy sites that have required extensive modifications and suffer constraints of size, water depths, and land access. Even where new terminals have been built in Europe, such as the Second Maasvlatke in Rotterdam or Deurganck in Antwerp, their planning and construction phases spanned over a decade, in contrast to major projects in China that were conceived and completed in three years and can respond more quickly to market conditions.

In North America new infrastructures are almost impossible to develop because of environmental legislation and citizen's opposition, and as a result modernisation tends to involve modifying existing infrastructures, which is costly and in many cases sub-optimal, resulting in longer ATTs. The result is that in both land and capital inputs the major Asian ports stand generally far ahead of those in North America.

The differences are enhanced by labour conditions. In Asia dock labour has been shown to be more flexible, in particular agreeing to more shifts that enable terminals to remain open 24 hours a day, seven days per week and are less prone to take breaks. Shifts begin when the ship arrives and not at a fixed time. In a recent study of the competitiveness of Chinese and Korean ports involving 19 independent variables the strongest component extracted in a factor analysis that accounted for 13% of total variance related to labour flexibility (Yeo et al., 2008). At the other extreme are ports in North and South America where strong labour unions have fought many attempts to introduce more flexible work practices. The power of the unions on the west coast of the USA is particularly great. All job assignments within the terminals are decided by the union, with daily allocations being made on the basis of 'low-man-out' dispatching, which gives the jobs to the workers who have the fewest accumulated hours (Bonnacich and Wilson (2008). This ensures fairness rather than allocation based on performance, ability or experience.

Table 6 Correlations between ATT and total port container throughput by region, 2013

Region	*Med*	*S. Asia*	*ECNA*	*WCNA*	*NWEur*	*E and N Asia*	*Global*
Number of ports	6	5	8	8	9	16	52
r	0.04	0.70	0.81*	0.76*	0.56	.26	–0.03

Note: *Significant at p .05.

In Table 6 simple correlations between the time performance of ports and total port traffic broken down by region reveal much higher associations than those at the global level, although in only two cases are the results statistically significant, because of the small sample sizes.

4.4 ATTs of transhipment ports

A further example of port differentiation is that of primary function. It is claimed in the literature that transhipment ports require very high levels of efficiency in comparison to other ports because their customers are footloose (Cullinane et al., 2006). There is further logic to this since in transhipment ports containers stay in the terminal and are under the complete control of the terminal operator, whereas in gateway ports containers are dependent on the delivery and pick up schedules of shippers, which makes yard planning more complex. Twelve of the ports in this study have transhipments comprising the majority of their traffic. As can be seen in Table 7, all but three have shorter than average ship dwell times in port. Both Singapore and Jebel Ali (Dubai) are major bunkering ports and this that may extend their ATTs. The case of Kingston is unaccounted for at present. When ATTs for the 12 transhipment ports are correlated with traffic (container throughput) a statistically significant (at p .05) r = 0.61 is obtained.

Table 7 Port dwell times of ships at transhipment ports (in hours)

Kingston	*Balboa*	*Colon*	*Singapore*	*Tanjung Pelepas*	*Colombo*
29.51	19.04	19.27	31.42	22.36	19.63
Algeciras	Sines	Marsaxlokk	Tanger-Med	Jebel Ali	Salalah
17.73	24.91	12.47	15.01	29.06	17.03
Average of all ports: 25.54 h					

This evidence confirms the relative efficiency of transhipment ports, and complements the argument that time performance reflects many factors that are not linearly related across the total spectrum of ports.

5 Conclusions

The review of the maritime transport literature has revealed the importance of time in port operations as well as in the selection of transport chains. It is seen as the complement of cost as a key factor in port efficiency and chain fluidity. Up until recently it has been impossible to obtain comprehensive time metrics concerning the duration of port calls in container shipping, and this has constrained academic analysis. Employing data recently made available by the mandatory geo-positioning of ships established by the International

Maritime Organisation, this paper has produced estimates of the ATTs of 70 ports engaged in the three main east-west trade routes and one north-south trade.

A number of important conclusions can be drawn from this research. First, the average ATT varies considerably between ports. Second, the study was unable to identify a clear relationship between the number of containers handled and ATTs. Third, the relation between ATTs and indicators of port efficiency reveal a lack of correlation. Fourth, ATTs exhibit a pattern of considerable regional diversity. Markets differ: some are oriented to exports; some are located close to the ports while others are located hundreds of kilometres away. Land access to ports differs: some require passage through urban agglomerations, while other terminals are on greenfield sites. The use of berthing space, crane deployment, the flexibility of labour and the linking ship calls with hours of work, terminal layout, and intermodal connections reflect regional and local operating conditions. Finally, it is demonstrated that transhipment ports exhibit shorter ATTs than the other container ports.

Container shipping is usually regarded as a global industry, indeed it is cited as one of the drivers of globalisation. The main ocean carriers operate global services, and most of the major port terminals are operated by international terminal companies. Yet this study suggests that ships' times in port are shaped by regional and local factors. The differentiation between port regions indicates that consideration of global industry-wide factors may not be a useful approach therefore. The example of transhipment ports indicates that port functions provide another distinguishing characteristic that has to be taken into account. This suggests that research into port efficiency should carefully consider scalar, functional and spatial dimensions of the data.

Our ongoing research is exploring how ATTs themselves can be further disaggregated by measuring differences between terminals within the same port as well as between the different carriers whose vessels make the service calls. Early results indicate that there are considerable differences in the ATT scores of both terminals and carriers, adding another dimension to the issue of port time. The other approach being pursued is the question of punctuality. The analysis of ATTs considered in this study has ignored the time variance of service calls, but the lack of consistency in vessel arrivals is seen by the industry and customers as one of the major challenges facing the shipping industry.

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References

Agarwal, R. and Ergun, Ö. (2008) 'Ship scheduling and network design for cargo routing in liner shipping', *Transportation Science*, Vol. 42, No. 2, pp.175–196.

Bonnacich, E. and Wilson, J. (2008) *Getting the Goods, Ports, Labor and the Logistics Revolution*, Cornell University Press, Ithaca.

Brooks, M.R. (1993) 'International competitiveness – assessing and exploring competitive advantage by ocean container carriers', *Logistics and Transportation Review*, Vol. 29, No. 3, pp.275–293.

Brouer, B.D., Dirksen, J., Pisinger, D., Plum, C.E.M. and Vaaben, B. (2013) 'The vessel schedule recovery problem (VSRP) – a MIP model for handling disruptions in liner shipping', *European Journal of Operation Research*, Vol. 224, No. 2, pp.362–374.

Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2015) *Waterline*, Vol. 56, Statistical Report, BITRE, Canberra.

Cariou, P. (2012) 'Is slow steaming a sustainable means of reducing CO2 emissions from container shipping?', *Transportation Research Part D*, Vol. 16, No. 3, pp.260–264.

Chang, Y-T., Lee, S-Y. and Tongzon, J.L. (2008) 'Port selection factors by shipping lines: different perspectives between trunk liners and feeder service providers', *Marine Policy*, Vol. 32, No. 6, pp.877–885.

Comtois, C. and Slack, B. (2009) *Developing Key Port Utilization Indicators (KPUI) for Canada's Bulk Ports*, Transport Canada, Ottawa.

Cordeau, J-F., Laporte, G., Legato, P. and Moccia, L. (2005) 'Models and tabu search heuristics for the berth-allocation problem', *Transportation Science*, Vol. 39, No. 4, pp.526–538.

Cullinane, K. and Song, D.W. (2006) 'Estimating the relative efficiency of European container ports: a stochastic frontier analysis', *Research in Transportation Economics*, Vol. 16, No. 1, pp.85–115.

Cullinane, K., Wang, T.F., Song, D.W. and Ji, P. (2006) 'The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis', *Transportation Research Part A: Policy and Practice*, Vol. 40, No. 4, pp.354–374.

Ducruet, C. and Notteboom, T. (2012) 'The worldwide maritime network of container shipping: spatial structure and regional dynamics', *Global Networks*, Vol. 12, No. 3, pp.395–423.

Ducruet, C. and Zaidi, F. (2012) 'Maritime constellations: a complex network approach to shipping and ports', *Maritime Policy and Management*, Vol. 39, No. 2, pp.151–168.

Ducruet, C., Itoh, H. and Merk, O. (2014) 'Time efficiency at world container ports', *International Transport Forum/OECD*, Paris, 30pp.

Ducruet, C., Rozenblat, C. and Zaidi, F. (2010) 'Ports in multi-level maritime networks: evidence from the Atlantic (1996–2006)', *Journal of Transport Geography*, Vol. 18, No. 4, pp.508–518.

European Seaports Organisation (2012) *European Port Performance Dashboard* [online] http://www.espo.be/images/stories/Publications/studies_reports_surveys/espo_dashboard_2012.pdf (accessed 1 June 2016).

Grosso, M. and Monteiro, F. (2009) 'Relevant strategic criteria when choosing a container port-the case of the port of Genoa', *Proceedings of the International Conference on Prospects for Research on Transport and Logistics*, Dogus University, Turkey, pp.139–160.

Imai, A., Nishimura, E. and Papadimitriou, S. (2008) 'Berthing ships at a multi-user container terminal with a limited quay capacity', *Transportation Research Part E*, Vol. 44, No. 4, pp.136–151.

Journal of Commerce (2014) 'Berth productivity', JOC Group, July, p.26.

Kozan, K. (2000) 'Optimising container transfers at multimodal terminals', *Mathematical and Computer Modelling*, Vol. 31, Nos. 10–12, pp.235–243.

Lin, L.C. and Tseng, C.C. (2007) 'Operational performance evaluation of major container ports in the Asia-Pacific region', *Maritime Policy and Management*, Vol. 34, No. 6, pp.535–551.

Lu, B., Park, N. and Huo, Y. (2015) 'Operational efficiency evaluation of the world's leading container seaports', in Mi, W., Lee, L.H., Hirasawa, K. and Li, W. (Eds.): 'Recent developments on port and ocean engineering', *Journal of Coastal Research*, Special Issue, No. 73, pp.248–254.

Malchow, B. and Kanafani, A. (2001) 'A disaggregate analysis of factors influencing port selection', *Maritime Policy and Management*, Vol. 28, No. 3, pp.265–277.

Notteboom, T. (2006) 'The time factor in liner shipping services', *Maritime Economics & Logistics*, Vol. 8, No. 1, pp.19–39.

Panayides, P.M., Maxoulis, C.N., Wang, T-F. and Ng, K-Y.A. (2009) 'A critical analysis of DEA applications to seaport economic efficiency measurement', *Transport Reviews*, Vol. 29, No. 2, pp.183–206.

Peters, H.J. (2001) 'Developments in global seatrade and container shipping markets: their effects of the port industry and private sector involvement', *International Journal of Maritime Economics*, Vol. 3, No. 1, pp.3–26.

Reinhardt, L.B., Plum, C.E.M., Pisinger, D., Sigurd, M.M. and Vial, G.T.P. (2016) 'The liner shipping berth scheduling problem with transit times', *Transportation Research Part E*, February, Vol. 86, pp.116–128.

Saeed, N. and Aaby, B. (2013) 'An Analysis of factors contributing as selection criteria for users of european container terminals', Paper presented at *Transportation Research Board*, Washington, USA, January.

Saldanha, J.P., Russell, D.M. and Tyworth, J.E. (2006) 'A disaggregate analysis of ocean carriers' transit time performance', *Transportation Journal*, Vol. 45, No. 2, pp.39–60.

Saldanha, J.P., Tyworth, J.E., Swan, P.F. and Russell, D.M. (2009) 'Cutting logistics costs with ocean carrier selection', *Journal of Business Logistics*, Vol. 30, No. 2, pp.175–195.

Sanchez, R.J., Hoffman, J., Micco, A., Pizzolitto, G., Sgut, M. and Wilmsmeier, G. (2003) 'Port efficiency and international trade: port efficiency as a determinant of maritime transport costs', *Journal of Maritime Economics and Logistics*, Vol. 5, No. 2, pp.199–218.

Slack, B. (1985) 'Containerization, inter-port competition and port selection', *Maritime Policy and Management*, Vol. 12, No. 4, pp.293–230.

Song D-P., Li, D. and Drake, P. (2015) 'Multi-objective optimization for planning liner shipping service with uncertain port times', *Transportation Research Part E*, February, Vol. 84, No. 1, pp.1–22.

Song, D.W. and Yeo, K.T. (2004) 'A competitive analysis of Chinese container ports using the analytic hierarchy process', *Maritime Economics and Logistics*, Vol. 6, No. 1, pp.34–52.

Tongzon, J. (2001) 'Efficiency measurement of selected Australian and other international ports using data envelopment analysis', *Transportation Research Part A*, Vol. 35, No. 2, pp.113–128.

Tongzon, J. and Heng, W. (2005) 'Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)', *Transportation Research Part A: Policy and Practice*, Vol. 39, No. 5, pp.405–424.

Tongzon, J.L. (2009) 'Port choice and freight forwarders', *Transportation Research Part E*, Vol. 45, No. 1, pp.186–195.

Tongzon, J.L. and Sawant, L. (2007) 'Port choice in a competitive environment: from the shipping lines' perspective', *Applied Economics*, Vol. 39, No. 4, pp.477–492.

Turner, H., Windle, R. and Dresner, M. (2004) 'North American container port productivity: 1984–1997', *Transportation Research Part E*, Vol. 40, No. 4, pp.339–356.

Vernimmen, B., Dullaert, W. and Engelen, S. (2007) 'Schedule unreliability in liner shipping: origins and consequences for the hinterland supply chain', *Maritime Economics and Logistics*, Vol. 9, No. 3, pp.193–213.

Wiegmans, B.W., van der Hoest, A. and Notteboom, T.E. (2008) 'Port and terminal selection by deep-sea container operators', *Maritime Policy and Management*, Vol. 35, No. 6, pp.517–534.

Yeo, G-T., Roe, M. and Dinwoodie, J. (2008) 'Evaluating the competitiveness of container ports in Korea and China', *Transportation Research Part A*, Vol. 42, No. 6, pp.910–921.

Zhang, A., Lam, J. and Huang, G. (2014) 'Port strategy in the era of supply chain management: the case of Hong Kong', *Maritime Policy and Management*, Vol. 41, No. 4, pp.367–383.