The Return on Investment of Big Containerships: The Impact of Port Time, Vessel Size and Multiple Ports of Call

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Abstract

Containerships are getting bigger (wider, longer and taller). Realizing the benefits of increasing containership size requires full capacity utilization to justify the high capital investment. Major container ports have not been able to increase the necessary productivities corresponding to the increase in ship size. Keeping up with the new vessel size discharge (import) and load (export) (D&L) technology requirements to service the large containerships have led the liner industry to form alliances that maximize carrying capacity and to call multiple ports per voyage to maintain schedule integrity. Evidence indicates that large containerships’ round-trip voyage times have increased substantially. The authors find that large containerships exhibit more time at the pier for D&L operations due to their large dimensions, notably the beam size. Each increase in beam size increased port time by 4.5 hours, and the increase in the number of ports of call by one percent increased port time by three percent. All of this negatively affects the return on investment on containerships.

The paper focuses on the port and sea time operations consequential to the increase in a vessel’s size and its impact on asset utilization and thus the return on investment with respect to time. Specifically, the focus is on the dominating port time increase due to the increase in beam size which spills over to the number of ports of call impacting the return on investment. The paper recommends that ports improve terminal productivity and operation efficiency for the liner service to reduce the number of ports of call. Thus, ports that resolve these deficiencies will gain a competitive edge and provide better return on investment to their customers.

Key words: large containerships, return on investment, port time, ports of call, vessel size, containership utilization
Introduction

The increase in containership size has been in effect for many years and is expected to continue. Presently the world fleet includes 37 ultra large containerships that are larger than 20,000 Twenty-foot Equivalent Units (TEU),1 more than 300 ships are larger than 13,000 TEU, and the six largest containerships are 21,413 TEU each. In 2019 alone, 11 containerships of 23,000 TEU are expected to be delivered. Larger containerships are on the horizon (List of Largest Containerships, 2018). In 2017 the global fleet size was 19 million TEU; in 2022 the global fleet is expected to be about 23 million TEU (Knowler, 2017a).

The large and ultra large containerships impact significantly the vessels’ utilization of time due to their dimensions, especially width or beam (59 meters), length (400 meters) and height and the new operation standard of calling multiple ports per voyage. The trend of increasing containership size is to take advantage of their economies of scale at sea, but the unintended consequence of the carriers is diseconomies of scale at the port. There are two conflicting aspects. To realize the benefits of economies of scale, full capacity utilization of the ship is necessary, but this will increase the number of containers per cargo bay, thus resulting in longer load and discharge time for each cargo bay. This will force the large containerships to increase the number of ports of call to capture more cargo to fill up the ship, resulting in longer aggregate port time in a voyage. Furthermore, major container ports have not been able to increase productivity corresponding to the increase in vessel size. The latter is the bottleneck of the operation which spills over to containerships’ increase in their number of ports of call in a voyage and congestion outside the port.

Evidence from several years indicates that large containerships’ round voyage time has increased substantially. Larger containerships also exhibit more time in port for D&L operations due to their large dimensions notably the beam size. Beam size is expressed in the number of containers across the ship’s deck; for every additional container in beam size, the ship’s port time increased by 4.5 hours (Yahalom and Guan, 2016), and for one percent increase in the number of ports of call, port time increased by three percent (Guan and Yahalom, 2017).

The return on investment of a containership is directly linked to the asset’s performance, i.e., containership utilization with respect to time. Containership utilization is determined as a system that is, the combination of both sea time and port time. Given the excess carrying capacity in the industry (Knowler, 2017a), the potential growth is excluded from the analysis.

The paper focuses on the port and sea time operations consequential to the increase in a vessel’s size and its impact on asset utilization and thus the return on investment with respect to time. Specifically, the focus is on the dominating port time increase due to the increase in beam size which spills over to the number of ports of call impacting the return on investment.

Literature Review

A containership maximizes its return on investment by transiting fully loaded and by maximizing the number of voyages per year. Maximizing the load frequently leads carriers to form alliances. An alliance (Freight Hub, 2017) in the “shipping industry is a group of ocean carriers joining forces to create a cooperation agreement forming a strategic alliance covering various trade routes

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1 One TEU is equivalent of a 20-foot container with the dimension of 20 x 8 x 8.5 (length, width, and height in feet).
through cooperation between its members on a global level.” Maximizing the number of voyages per year is best realized by a shuttle service between two ports.

The literature review addresses various segments of the sea and port time issues. However, there is no address of return on investment with respect to the system’s operation time or utilization. The literature review focuses on the sea and port time segments.

Yahalom and Guan (2016) establish that beam or bay size is the dominating factor of pier time and as bay size increases, the average cargo handling time of two bays increases by an average of 4.5 hours at any productivity level. In addition, they find that bay time declines as crane productivity increases up to the crane’s technological constraint, and that the larger the beam/bay, the larger the marginal benefits when productivity increases. Guan and Yahalom (2017) find that a one percent increase in ship size and its auxiliary industry operations, increase port time by nearly 2.9%, i.e., diseconomies of scale at the port. Cullinane, et. al. (1998) identify port time as a schedule-planning instrument and the consequences of deviating from it. Cullinane, et. al. (2000) indicate that a ship’s overall performance should consider the entire voyage, not only sea time. They also indicate that port time is affected by cargo exchange, crane density, average crane productivity, down time in port, and working schedule. Gilman (1976) mentions port time as a handling performance measure. Vulovic (1999) is concerned that the port industry does not match large ship needs of minimizing port time. Ducruet, et. al. (2014) address the time factor in port performance and efficiency for container vessels, finding that port location (country and region) is important in port performance and efficiency. They also indicate that “three composite indices about logistics performance, port infrastructure quality, and global connectedness did not play a statistically significant role on time efficiency.” They address port time in the same way as Moon (2013), who include congestion as a component of port time. Suarez-Aleman, et. al. (2013) show that “port time is the combination of several components, such as port access time, loading and unloading times, ship waiting time, and time for customs and other administrative procedures.” Sys, et. al. (2008) write about extended port time, the rationale of using big ships and the need for making up lost port time with higher speed. Tozer and Penfold (2001) discuss port time with respect to differences in containership size, annual costs and the number of annual voyages. Cullinane, et. al. (1999) address the economies of scale of large ships and port productivity improvements on diseconomies of scale in port. McLellan (1997) indicates that there are practical limits to ship size that can be imposed on a port, including draft, space, container handling technology, and infrastructure. Brett (2015) refers to a Drewry Insight study, indicating that “while overall berth productivity improves with larger vessels, it does not increase in line with vessel sizes. … This means that the number of gantry cranes deployed cannot be increased in direct proportion to increased ship sizes. … as vessels become larger, the crane trolley has to move further for each move, slowing productivity.” This last finding indicates diseconomies of scale in port due to increasing ship size. In short, there is a consensus by many that the port became a critical point of diseconomies of scale to the economies of scale of a large containership.

The key change in the containership market that impacts the transport system is economies of scale. Other impacts come from environmental concerns, integration of information technologies, progress in terminal automation, ship financing, security issues, and real estate pressures around terminal facilities (Drewry, 2015). Wijnolst, et. al. (1999) state that the driving force is the creation of a competitive advantage through economies of scale. Economies of scale in liner shipping have been increasing in response to technology-driven productivity growth, regulatory changes, and higher world-wide trade flows (Gregory, 2000). The Financial Times reported Maersk’s Triple E
Class containership (18,000 TEU) to be 26 percent more cost efficient at sea than the E class
(15,000 TEU) (Wright, 2011). However, OECD/ITF (2) reports that a 19,000 TEU modern vessel
is only about 15 percent more efficient than a 15,000 TEU at a speed of 22 knots.

Economies of scale from operating larger containerships can be achieved if: vessels are full, the
number of ports of call decreases, shipping distance increases, the relative costs of large ships
decrease, and port productivity improves (Hsu and Hsieh, 2005; Cullinane and Khanna 2000). The
deployment of the new generation of containerships is mainly due to economies of scale, assuming
high utilization of the larger ships (Sys, et. al. 2008). However, due to the lack of ship capacity
utilization, shipping companies try to reduce operating costs. The reduction of operating cost
includes: optimization of the ship size, speed, fuel efficiency, sailing frequency, different routes
and port calling mode (Sys, et. al. 2008; Etsuko, et.al., 2006; Wigforss 2012; Khor, et. al. 2013;
Hsu and Hsieh, 2005).

The aggregate economies of scale in containership operation is a trade-off between the positive
returns at sea and the negative returns in port (Jansson and Schnepson, 1987). The obvious
optimizing factors are the design and capability of the quay (draught, strength) and the quay cranes
(outreach, air draft). Other factors are the yard and the yard handling equipment, especially in
response to cascading (OECD/ITF, 2015). Yahalom and Guan (2016) demonstrated that the
minimum port time for containerships is a function of a vessel’s beam size; the larger the vessel’s
beam size, the more time a vessel needs to discharge and load. Thus, ports can mitigate this factor
with higher gantry crane productivity.

Ports control factors such as berth length and the number of gantry cranes. However, terminals
with an excess number of gantry cranes could face high idle costs due to excess idle time.
Furthermore, the larger vessels improve crane productivity initially up to a point of diminishing
returns, when the crane-working cycle time increases because the container bays are larger and
deeper (Yahalom and Guan, 2016, OECD/ITF, 2015, and Le, 2013). Additional diminishing
effects are due to the larger hatches and therefore the lessening of gantry crane movements.
Cullinane and Khanna (1998) argued that there are no diseconomies of scale in port for ship sizes
of less than 1500 TEU and that the economies of container ship operations are crucially dependent
on port productivity. Two years later, Cullinane and Khanna (2000) argued that at least in the
vessel size range of 6,000 to 7,000 TEU, there are net positive returns to scale such that the cost
savings while at sea outweigh the additional costs in port. There is no doubt that the productive
capacity of the port has improved. As a result, the critical vessel size (number of TEUs) also
increased. However, vessel size has a ceiling depending on the port’s productivity.

Larger vessels experience longer vessel arrival delays and longer berth times than smaller vessels.
Over 60% of vessel arrival delays exceed 24 hours for vessels with a capacity of 8,000 TEU at
both ports LA/LB. The impact is worldwide. In Asia, ships of more than 10,000 TEU had the
highest average arrival delay, with an average delay of 19 hours in Shenzhen and 23 hours in Hong
Kong (Knowler, 2014). This is no surprise, as indicated by Yahalom and Guan (2016).

The bigger the ship, the larger the number of hours spent in port; an increased port stay is a
diseconomy of scale (Cullinane and Khanna, 2000). To guarantee the economies of scale for bigger
container ships, the average turnaround time (ATT) is important. It includes the time spent entering
the port, loading, unloading, and departing, i.e., ship-to-shore operations, other terminal operations
and port functions (Ducruet. et. al. 2014).
In summary, the studies above focus on containership economies of scale based on voyage costs per TEU. The literature review did not find any reference or analysis regarding the return on investment of sea and port time for large containerships. This paper focuses on port time based on the number of vessels in an alliance service, average vessel size and the number of ports of call. This, in our view, is a critical factor in determining the future investments in large containerships.

**Methodology**

Containership operations are divided between sea time and port time. A containership maximizes utilization when both port time and sea time are minimized, which enables a larger number of voyages per year. Minimizing sea time is realized in a shuttle service between two ports. Minimizing port time is attained when a containership D&L’s at a minimum amount of time. These two assume normal operation conditions without disruptions in operation.

Most global ports cannot handle the large and ultra large containerships’ objective to D&L all the containers in one port. The difficulties are mainly due to:

- the liner service schedule and keeping its integrity
- the amount of export and import freight generated and demanded in each port including the imbalance between export and import containers in each port
- the amount of space available in each port for container storage for import and export
- gantry crane D&L output level (productivity)
- container terminal (yard) operation technology
- the distribution between 20’ and 40’ containers
- the stowing plan for D&L in each port of call
- terminal management challenges

Therefore, the large and ultra large containerships call several ports in a voyage or loop. In each port a different number of containers are D&L’d. Also, since a containership operation is on a schedule (liner service) usually once a week, delays impact the schedule’s integrity and therefore are undesirable. A scheduled operation also determines the number of imports and exports that are D&L’d in each port, especially for the large and ultra large containerships.

The very large and ultra large containership itself is wider (beam size), longer and higher. These dimensions, especially the beam, require more time at the container terminal for D&L (Yahalom and Guan, 2016). Furthermore, given the gantry crane technology, operations and safety constraints, frequently one crane is deployed every 50 meters of quay, blocking four containership bays. For example, a containership of 400 meters could be serviced by eight gantry cranes at a time. These constraints impact port time. Therefore, the D&L limitations of a port together with the liner service schedule integrity requirement spillover into containerships calling multiple ports.

Calling multiple ports directly impacts containership utilization. Each diversion from the route to call a port reduces the number of annual voyages a vessel makes, i.e., vessel’s utilization which impacts the return on investment. However, there is also the consideration of the tradeoff between the large number of containers on board a vessel and calling multiple ports to deliver them. Are the operators better off financially deploying the liner service by calling multiple ports? The focus of this research is on the impact of ports’ inability to provide a shuttle service, causing the deviation from route due to multiple ports of call and its overall impact on the operation time.
The model is based on the Total Voyage Time (TVTi), which is the sum of the Total Port Time (TPTi)\(^2\) and Total Sea Time (TSTi)\(^3\) formally,

\[
TVTi = TSTi + TPTi
\]  \hspace{1cm} (1)

where \(i\) indicates the average vessel size in TEU.

The sea time voyage segment is determined by distance, cruising speed and scheduled arrival slot at the destination. The schedule is in full control by the captain and the firm in ordinary weather conditions. The reserved schedule arrival time slot at the destination assures the voyage’s economic benefits of fuel saving via slow steaming and virtual arrival.

Port time determination and the duration of stay due to liner service schedules are complex as indicated above. The challenges are captured by variables such as: Number of Vessels (NOV) en route, Vessel Size (VS) and the Number of Ports (NOP) of call. Thus, formally (equation 2),

\[
TPTi = NOVi + VSi + NOPi
\]  \hspace{1cm} (2)

From these variables one notes spillover of operating for large and ultra large containerships, i.e., the number of ports of call.

**Analysis**

Testing the model (equation 2), 2015 data of major shipping lines’ websites was used from Maersk, APL, CMA and Evergreen. The shipping line data for analysis was generated from 25 loops, which include 229 containerships serving 330 ports of call. The average containership size was 11,320 TEU, ranging from 4,250 to 19,000 TEU. The loops’ ports’ calling range was from 9 to 18 ports per loop. The range of voyage time per loop was 56 to 84 days (a multiple of seven), of which sea time ranged from 41 to 69 days and port time from 10 to 22 days.

The first test of a linear cross-section multiple regression analysis was calculated for the impact of the above variables on TPT. The calculations indicate that all the estimates are significant at 5% or better with a coefficient of determination (R\(^2\)) of 57.4%.

\[
TPT = 6.765 - 0.50\ NOV + 0.00049\ VS + 0.697\ NOP
\]  \hspace{1cm} (3)

\[\text{R}^2 = 57.4\%, \text{Adjusted } \text{R}^2 = 51.3\%, \text{ n} = 25, \text{ F-Stat} = 9.427\]

The estimates of equation 3 indicate that:

- NOV indicates that a service loop increase by one vessel reduces the total number of days in the port by 0.50 days or 12 hours (significant at 1.2%).
- VS indicates that an increase in vessel size by one TEU increases the port time by 0.000493 days or 1.2 minutes (significant at 2.3%). Alternatively, an increase of vessel size by 1000 TEU increases port time by 0.49 days or 12 hours.
- NOP indicates that an increase in the number of ports of call by one, increases the total port time by 0.697 days or about 17 hours (significant at 0.03%). This is also the dominating conclusion.

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\(^2\) TPTi is the time spent in the port/terminal from the moment a vessel is tied to the pier.

\(^3\) TSTi is TVTi less TPTi.
The test indicates that the port time (TPT) is dominated by the number of ports of call (NOP) in the loop. The impact of port time on the number of ports of call is very sensitive and very significant (equation 4). For example, using equation 4, a port time increase by two hours requires an additional port of call (0.569 x 2) to sustain service schedule integrity.

\[
\text{NOP} = 3.485 + 0.569 \text{TPT} \quad \text{(4)}
\]

\[
\text{T-Stat} \quad (1.383) \quad \text{Sig} \quad \text{or} \quad 0.18 \quad \text{or} \quad 0.0007%
\]

\[ R^2 = 39.83\%, \text{ Adjusted } R^2 = 37.2\%, \text{ n} = 25, \text{ F-Stat} = 15.21 \]

A second test, based on the same data, investigated the percentage change (logarithm) in total port time (equation 5) against the percent change of the same variables of equation 2 to determine their effect on port time. The elasticity results indicate their significant sensitivity to port time at 10% with a coefficient of determination \( R^2 \) of 52.3%.

\[
\log\text{TPT} = -4.825 - 0.161 \log\text{NOV} + 2.52 \log\text{VS} + 0.519 \log\text{NOP} \quad \text{(5)}
\]

\[
\text{T-Stat} \quad (-0.973) \quad (-1.789 \text{ or } 8.87\%) \quad (1.844 \text{ or } 7.99\%) \quad (3.576 \text{ or } 0.19\%)
\]

\[ R^2 = 52.3\%, \text{ Adjusted } R^2 = 45.2\%, \text{ n} = 24, \text{ F-Stat} = 7.31 \]

The regression results (elasticities) provide sensitivity measures of the change in port time due to each of the following:

- \( \log\text{NVP} \) indicates that as the number of vessels increase by one percent, total port time decreases by 0.16% (significant at 8.87%). This is a relatively small figure.
- \( \log\text{VS} \) indicates that as the vessel size (TEU) increases by one percent, port time increases by 2.52% (significant at 8%). This indicates that port time is very sensitive to vessel size. This is the dominating conclusion that is consistent and explained by Yahalom and Guan (2016) results.
- \( \log\text{NOP} \) indicates that as the number of ports of call increase by one percent, port time increases by 0.519% (very significant at 0.19%). Thus, ports are impacted by the liner service’s number of ports of call.
- The total effect of the increase in ship size \( (\log\text{NOV}+\log\text{VS}+\log\text{NOP}) \) on total port time is 2.878%. This is a very significant impact indicating the magnitude of the diseconomies of scale.

These sensitivities show the negative impacts on the return on investment with respect to time for the large and ultra large containership fleets and the pressure it imposes on the container terminal at the port to become more productive. This return on investment is consistent with Knowler (2017a) indicating:

“So with the existing world fleet we already have enough capacity (bold and underline in the source) to meet the world trade demand for the next four or five years, so the industry does not need any new capacity. This is going to be critical for the leading players to balance supply and demand going forward.”

Other critical areas affecting container shipping lines were highlighted by Drewry Managing Director Tim Power, and the analyst said he could see a more profitable industry emerging within the next five years.

“But capacity utilization must be at 90 percent or above all the time. If it isn’t, two things happen — your asset utilization is too low to be profitable, and everyone starts dropping
freight rates to try to hold on to market share. So, you lose money for two reasons,” he said.
“We can now see an industry that is sustainably profitable emerging in the next five years. Over the past five years the return on investment has been disastrous (underline by author), so why has anyone been continuing to operate in this industry? It’s because if they believe they will still be standing when paradise arrives, and they will be making lots of money.”

Conclusion

The paper, using statistical analysis, identifies key variables that dominate port time due to containership operation strategies, using their fleet to provide viable containership services at a reasonable port time.

The analysis found that, with the increase in containership size, port time increases, i.e., economies of scale that are gained at sea are lost at the port. The diseconomies of scale at the port are primarily due to ship size and the inability of the container terminal to increase corresponding productivity to handle the large number of boxes that the large and ultra large containerships carry, which spills over to calling many ports and the need for many vessels per liner service to maintain schedule integrity. This contributes to the negative cycle of diseconomies of scale at the port and the reduced return on investment of large containerships.

The analysis determined the sensitivity of port time to the changes in containership size, especially vessel size. As vessel size increases by one percent, port time increases by more than 2.5 percent. This dominating outcome is not a surprise because the discharge and load technologies at the port lag behind the demand for the large containerships needs (Yahalom and Guan 2018). Furthermore, the auxiliary effect of vessel size deployment strategy indicates an almost 2.9 percent increase in total port time. Obviously, other auxiliary factors play a role as well, such as port inefficiencies and the amount of equipment available, to name a few. All of these negatively affect the return on investment on large containerships.

Considering these findings, we recommend that ports improve terminal productivity and operation efficiency in order for the liner service to reduce the number of ports of call. These can be achieved with better D&L technology and its timely installation (Yahalom, at. al., 2018). Thus, ports that will resolve these deficiencies will gain a competitive edge and provide better return on investment to their customers. Furthermore, Knowler (2017a) also indicates and recommends:

“Economies of scale have to run out. It is essential that there is no point building a 24,000-TEU ship. When that happens, shipping lines will not have to build to lower unit costs, they will have to build according to demand.”

The second thing that had to happen was that consolidation continued (underline in source). “We have to get to a small number of carriers that are content with their market share. Keep capacity utilization at 90 percent on a sustainable basis and you will have a profitable business. With these two factors in play, the inelastic demand curve starts to work for you rather than against you. If the freight rate on the Adidas shoes is doubled, will that stop you buying that pair of shoes? Absolutely not. Shipping lines can double their freight rates, and nobody will notice.”

We recommend further research to determine long-term changes that would increase productivity in line with containership size and return on investment gains. Productivity improvements are expected from new technology and better performance. Furthermore, analysis should include the
economies of scale of aggregate operations to determine the overall benefits of large vessels and to their investors.

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