Baseline Sea Time for Containership Liner Service: A New Method to Evaluate Voyage Time Efficiency and Performance

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Abstract
Containerships have increased in size, thereby increasing in voyage time and the number of calling ports per voyage. The paper analyzes the impact of the increase in containership size on voyage time management. The authors developed a new and simple concept and standardized method, **Baseline Sea Time (BST)**, that measures voyage time efficiency. BST is the sea time between the first and last ports of call in a service loop, calculated by using standard distance between the two ports divided by average vessel speed. Using BST, the time spent on transit for multiple ports, harbor waiting, and port time is redefined and used to develop new standardized ratios/indicators to calculate voyage time utilization efficiency. Using an illustration, the study finds that calling multiple ports is equivalent to an additional 25.5% of voyage baseline time compared to a shuttle service. The cargo between the first and last ports of call spends an additional 63.8% of the voyage time staying on board when compared to a shuttle service. The new BST tools provide new prospects for analysis, comparison, policymaking, asset utilization, and voyage planning.

Keywords: Baseline Sea Time, Sea Time, Port Time, Voyage Time, Shuttle Service, Liner Service

1. Introduction

Containerships have been increasing in size. On May 8, 2020, the HMM *Algeciras,* a 23,964 Twenty-foot Equivalent Unit (TEU) containership, was set on her maiden voyage from Asia to Europe carrying 19,621 TEUs on board for The Alliance (Schuler, 2020), calling 11 ports both in Asia and Western Europe. This vessel is the first of a fleet of 12 24,000 TEU-class containerships. Orders for 22,000 TEU ships have been placed, 11 by MSC and nine by CMA CGM (Knowler, 2017), marking a new era of 20,000 plus TEU class. Currently, there are already 57 18,000 plus TEU ships in service, and another 73 are on the way (Luthwaite, 2017). This phenomenon accentuates the continuing trend of increasing vessel size.

The increase in containership size and volume carried is unmatched by an increase in port size and productivity (Yahalom and Guan, 2017). The increase in containership size triggers diseconomies of scale at the port because containerships (1) call many ports in a service loop on each voyage due to a limited number of containers discharged and loaded (D&L) per port, (2) spend more time in ports because port productivity is lagging behind the increase in vessel carrying capacity (Yahalom and Guan, 2016), and (3) have longer total Voyage Time (VT). That is a **new normal.** This new normal is perpetual in the liner industry which has not been measured and/or evaluated systematically for its efficiency, or lack of, due to the lack of evaluation tools, until now. VT is fundamental for a firm's competitiveness; the longer the voyage, the less attractive is the service for the customers. Customers prefer a shuttle service (SS). Thus, knowing the opportunity cost of this operational practice is instrumental for future industry development.

The paper introduces a new concept and standardized method of measuring liner VT efficiency (VTE), that is, **Baseline Sea Time (BST)** as its foundation. BST is a new practical and simple-to-apply standard based on time. BST is defined as **direct transit time** between the farthest ports of call in a multiport service loop, usually the first and last ports of call. BST is constant and built upon the shortest water route connecting two ports, equivalent to an SS. BST is calculated separately for each transit direction leg (back and forth) of the service loop (see below). Prior to BST, VTE was calculated in-house by each firm differently, usually comparing performance to a schedule. Firms' "on-time" claims could not be confirmed, and industry performance could not be compared because there was no generalized/standardized measure of VTE. This paper changes this ambiguity by providing a new robust and simple standardized methodology/tool for VTE determination, i.e., a break-through in standardizing performance measurement.

BST is used to develop a series of VTE ratios/indicators in a multiport call service such as intermediate ports of call transit time and harbor waiting time. Intermediate ports of call are defined as all the ports in the service loop other than the two farthest ports, normally the first and last ports. The newly created performance measures are in terms of BST, focusing on the overall amount of time a containership is off the BST course calling multiple ports (see method below).

The literature review is followed by methodology and an illustration of various ratios and indicators of a service loop. The paper closes with conclusions and implication recommendations.

2. Literature review

The literature of containership VT, Port Time (PT) and Sea Time (ST) of time efficiency and standards is limited. The literature does not address the relationships between the time segments that make up a voyage. Mooney (2017) indicates that 'Sustained effort needs to be put into improving data quality and participating in initiatives to develop suitable standards so that data can be worked with across different stakeholders in the container and shipping value chain.' Ducruet et al (2014) discuss and provide statistical analysis of time efficiency at world container ports, including measuring port efficiency and its determinants, and a comparison between ports globally. Notteboom (2006) discusses VT with respect to schedule reliability. Liu (2012) provides a general explanation of the three-time elements and divides PT between working time and idle time. Saggar (1970) offers a standard model for a typical ship's turnaround VT between the UK and India, focusing on time in the port, based on model variables of: route length, average speed, number of ports of call, and cargo loading and discharging rate. Slack and Comtois (2015) discuss ship time in a port from a comprehensive perspective, indicating that determining the ship time in port is a complex issue.

Economies of scale drive the building of large containerships. The economies of scale literature addresses different containership issues, indirectly VT, ST and PT. This literature review is clustered in categories to highlight the indirect impact on time.

General developments. Wijnolst et al. (1999) state that the operation's 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). Wright (2011) reported Maersk's Triple E Class containership (18,000 TEU) to be 26% more cost efficient at sea than the E class (15,000 TEU). OECD/ITF (2015) addresses various subjects focusing on the mega-ship impact on the port. With respect to port time, the OECD/ITF report indicates an increase in mega-ships' stays in port. Finally, we show that as vessel size increases by one percent, port time increases by more than 2.5 percent (Yahalom and Guan, 2019; Guan et al., 2017).

Vessel utilization. Economies of scale of operating larger tonnage can be achieved if: vessels are full, the number of ports of call decreases, shipping distance increases, 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 largely due to economies of scale, with high utilization of the larger vessels (Sys et al., 2008). Shipping companies have tried various means to reduce the operating costs. These means include optimization of ship size, speed, fuel efficiency, sailing frequency, different routes, port calling mode (Sys et al., 2008; Imai et al., 2006; Wigforss, 2012; Khor et al., 2013; Hsu and Hsieh, 2005), and “The tradeoff between vessel speed and the number of vessels required to maintain a given serve frequency” (Ng, 2018). Bigger containerships can benefit from economies of size. An optimal ship size and optimal speed are sensitive to load factor, sailing distance, labor time, bunker price, transport segment, terminal type, trade lane and technology (Wong et al., 2007; Sys et al., 2008). A ship that is optimal for one trade can be suboptimal for another. Speed reduction (slow steam, virtual arrival or time windows) is an important fuel efficiency measure. The bounds of the optimal number of ships to be deployed on a service route are subject to time windows (Ng, 2020). There are economies of scale from speed reduction due to the reduction of fuel consumption and anchoring time minimization for bigger containerships in a market recession period (Wigforss, 2012). Fuel price increase reduces cruising speed which “may require additional ships to operate a route” which ”may increase demand for containerships” (Ronen, 2011). Khor et al (2013) argued that 19.5 knots is the optimum speed, given the range of fuel cost of $650/ton to $750/ton, freight rate range of $1100/TEU to $1300/TEU and load factor of 40%. However, further cost increase could be realized with the increase in time of moving goods to market (Cullinane and Khanna, 2000).

Optimization. Jansson and Shneerson (1987) indicate that in a liner service, even if all the optimizations mentioned above materialize, there is no guarantee that bigger ships will have better economies of scale. The aggregate economic position (economies of scale) in the containership sector represents a tradeoff between the positive returns earned at sea and the negative returns accrued in port.

Port control. Generally, port control factors are berth length, the number of gantry cranes and their outreach. Larger vessels improve crane productivity up to a point of diminishing return, when the cranes' operating cycle times increase. Additional diminishing effects are due to the larger beams and therefore the lessening of gantry crane movements. Cullinane and Khanna (2000b) argued that at least in the vessel size range of 6000 to 7000 TEUs, 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. Thus, the critical vessel size (in TEUs) also increased. However, vessel size has a ceiling, depending on the port's gantry crane productivity (Yahalom and Guan, 2017).

Port stay. To assure the economies of scale for bigger containerships, knowing the Average Turnaround Time is important, because it includes the time spent in entering the port, loading, unloading, and departing, including ship-to-shore operations and other terminal operations and port functions as a whole (Ducruet and Merk, 2014).

Containerships stay at the port a certain amount of time to maintain their schedule integrity, which would maximize the economies of scale for the shipping line, especially in the European or the USA markets. Mongelluzzo (2014) identifies reasons why the Los Angeles-Long Beach (LA-LB) port, which handles bigger ships, larger cargo volumes and alliances, is congested. Over 60% of vessel arrival delays exceeded 24 hours for vessels with a capacity of 8000 TEUs at both LA-LB ports. In Asia, ships of more than 10,000 TEUs had the highest average arrival delay at Shenzhen and Hong Kong ports, with an average delay of 19 hours at Shenzhen and 23 hours at Hong Kong (Knowler, 2014). The bigger the ship, the larger the number of hours in the port, that is, diseconomy of scale (Yahalom and Guan, 2016, Cullinane and Khanna, 2000b). This is consistent with Yahalom and Guan (2016, 2017 and 2018), who demonstrated that the minimum PT for containerships is a function of the vessel's beam size, which can be mitigated with higher crane productivity.

Literature status. The literature review of VT and its segments ST and PT reveals that the existing calculation methods do not capture the essence of multiport voyage time.

The existing VT evaluation methods are per voyage, focusing on a voyage's distribution of time between ST and PT, such as the percentage of on-time performance that meets published schedules and vessel turnaround time in individual ports. Some authors used distance between ports as a variable in their research. But, since timewise each service loop of multiport of call is different, the existing methods are not standardized for voyage comparisons and analysis between different loops and therefore are limited in use. Hence, the current methods of performance evaluation and comparison of long VT, due to multiport of call, do not provide standardized tradeoff insights between the increase in vessel size, the increase in the number of ports of call and the additional time it takes to call multiple ports. Therefore, a comparison of internal and cross-industry transit times is impossible for studying the aggregate VT and the reasons for the basic structural increase of transit time.

Operation insights, in addition to comparisons, are a key for analysis of operational success, economic and resources allocation, problem solving, enhancing compatitivness and seeking new opportunities. Many of these insights and other analytical and decision-making issues addressed above would have benefited from having the BST standardized tools developed below, which are the focus of this research.

3. Methodology

3.1 Background

The VT of a containership service loop is comprised of two main segments, ST and PT. The longer the VT, the fewer the voyages per year and the longer the time cargo stays onboard, reducing vessels' utilization of time and increasing holding costs to cargo owners. Therefore, routing and scheduling the ports of call for large containerships, especially mega containerships, are challenging. The challenge is to develop a standardized and measurable analytical tool(s) that leads to better understanding of multiport operations that also minimizes diversion from the main navigation course, thereby minimizing voyage time.

On the *supply side*, the objective of the weekly liner service operator is to maximize container carrying capacity driven by the vessel's economies of scale at sea. Therefore, the operating model of the current state of the container shipping industry is via:

1. Consolidation (mergers and acquisitions, CMA CGM/APL, Shipping/OOCL, COSCO/China, Hapag Lloyd/UASC)
2. Concentration of top-ranking carriers in three major alliances (2M, Ocean, and The Alliance)
3. Further increase in containership size in major trade routes, especially in the Asia–Europe and Transpacific routes.

On the *demand side*, the contemporary liner shipping operation is driven by customer demand for cargo subject to operation constraints and tradeoffs.

The operation constraints where operators have limited control include:

- The demand for cargo of less than a full containership per port per voyage
- Weekly containership liner service. Operationally, using large containerships

increases the number of ports of call per voyage loop.

The tradeoffs where operators exercise control include the choice to:

- Maximize carrying capacity on large containerships and increase the number of ports of call, both of which increase the VT, and/or
- Minimize voyage time by operating smaller vessels, reducing the number of port calls, to a minimum of an SS between two ports.

The operation model of the ongoing liner service is both accommodating consumer demand and calling multiple ports per voyage, thereby maximizing vessel carrying capacity while paying in time (opportunity cost of time). Knowing the opportunity cost per voyage and annually is instrumental in improving performance and investments in the industry.

The liner shipping services is either an SS or a multiport of call service. An SS is between the port of origin and the port of destination (O-D). The SS is time efficient since ships travel only between two ports. In a multiport of call service, a vessel calls several ports along a service loop; therefore, it is less time efficient than an SS, due to the additional amount of time of calling multiple ports.

The paper develops a new method for determining containership VTE of the two key voyage segments (ST and PT) and their respective sub-segments (see below). These segments and sub-segments of time, included in the new BST concept, are a key for firms' performance analysis internally and industry wide. BST enables firms to set performance targets and verify compliance. The method and its indicators merit new analysis for decision-makers for determining the cost of adding a vessel and/or a port of call to a voyage. The indicators are also key inputs in firms' operation decisions for service planning, asset utilization, capital investment and operational performance. These decisions are especially important in times of a large increase in containership size, increase in the number of megaships deployed, increase in the number of ports of call per voyage, and changes in industry alignment.

3.2 Containership voyage time, its segments and performance indicators

A containership's Voyage Time (VT) between O-D of an SS and/or a multiport of call service is the sum of Sea Time (ST) and Port Time (PT). Formally:

$$VT = ST + PT \qquad (1)$$

A service loop of a multiport of call has tradeoffs. Vessel capacity utilization increases, realizing the benefits of the economies of scale that a large ship provides, but at a cost; ships call multiple ports to secure sufficient cargo volume. This leads to longer total VT at a lower VTE.

The extensive increased use of multiple ports of call per voyage shows that presently the voyage segments are aggregated and are divided between ST and PT. Instead, the analysis will benefit from disaggregating VT into four redefined segments, ST made-up of BST, IPTT, HWT and PT, from equation 1:

$$VT = BST + IPTT + HWT + PT \qquad (2)$$

where:

BST is the transit time between the two farthest ports of call in the loop, as in an SS.

IPTT is the sum of all the Intermediate Ports of Call Transit Times between the two farthest ports in a service loop, i.e., IPTT does not include the origin and destination ports (the two farthest ports). For example, a two-hour inbound diversion from the main course to call an intermediate port and two-hour outbound return from the intermediate port to the main course counts for four hours per IPTT. Thus, in the aforementioned, a route with nine ports of call totals 28 IPTT hours [(9-2) intermediate ports x 4 hours)].

HWT is the sum of all the Harbor Waiting Time before berthing.

PT is the sum of all the PT in the multiport service. In the aforementioned example where each port takes 24 hours to D&L, PT totals nine days. PT can be defined as the time either between berthing and unberthing (pier-to-pier time - PRT) or between pilot boarding on arrival and unboarding on departure (pilot-to-pilot time - PLT).

Using these segments, Multi-Ports of Call Time (MPCT) is the additional voyage time due to the multiple ports of call which is the difference between VT and BST:

$$MPCT = VT - BST = HWT + IPTT + PT$$

The time of each voyage segment in a large containership's operation provides insights into its performance captured by ratios/indicators. The definition and analysis of the new VT segments, elaborated in considerable detail, start with BST, IPTT and HWT.

3.2.1 Baseline Sea Time (BST)

The **new Baseline Sea Time (BST) concept** and model were developed to provide a compelling analytical and comparison base. BST is founded on an opportunity cost principle seeking to answer the hypothetical question: What is the ST of a multiple ports of call voyage if the voyage skips all the intermediate ports of call and instead acts as an SS between the two farthest ports, one in each location? In this respect, BST is equivalent to an SS transit time which is practical and quantifiable.

BST is **defined** as the voyage's ST based solely on the distance in Nautical Miles (NM) between the two farthest ports in the loop and the vessel's average travel speed, equivalent to an SS transit time. BST is **calculated** by using the standard distance over speed, which is 'time', that is, dividing the distance between the first and last ports of call in a service loop by the vessel's average operating speed. For example, a service loop of 10,000 NM of non-stop service between the first and last ports at an average speed of 20 knots takes 500 hours (20.8 days). BST is a simple generic **standard** to obtain. Other factors of round trip, speed, virtual arrival, and slow steaming could be used to obtain a different standard or baseline.

BST as a standalone figure has limited value and use. But, in the context of equation 3 and its correlation with the other variables in the equation, BST is the foundation for a host of important new performance measures to be used widely. Equation 3 standardizes the voyage segments of equations 1 and 2 with respect to BST by dividing their segments by a standardized common denominator, BST. Equation 3 represents a distribution of time based on distance and speed between voyage segments.

$$\frac{\mathrm{VT}}{\mathrm{BST}} - 1 = \frac{\mathrm{ST} + \mathrm{PT}}{\mathrm{BST}} - 1 = \frac{\mathrm{IPTT}}{\mathrm{BST}} + \frac{\mathrm{HWT}}{\mathrm{BST}} + \frac{\mathrm{PT}}{\mathrm{BST}} = \frac{\mathrm{MPCT}}{\mathrm{BST}} \tag{3}$$

The distribution between the ratios and their changes by voyage and over time is used as tools of analysis, comparison, and changes in IPTT, HWT and PT, independent of VT and ST. A change in IPTT, HWT or PT provides robust ratios/indicators via a standardized baseline. All the performance measures are in relative terms of BST focusing on the overall amount of time a containership is off the BST course to call multiple ports (see illustrations below). Equation 3 is the foundation for performance measures outlined in table 1 with their expected and optimal values, which is explained in detail below.

Table 1: BST performance ratios and indicators (one-way voyage)

Indicator/ratio	Name of indicator/ratio	Optimum value	Expected value
IPTT/BST	Intermediate Port of Call Transit Time Ratio	Small	<1
HWT/BST	Harbor Waiting Time Indicator	0	<1
(IPTT+HWT)/BST	Vessel Total Opportunity Cost Time Ratio	Small	<1
ST/BST	Sea Time Performance Indicator	1	>1
VT/BST	Voyage Time Performance Indicator	A constant	>1
MPCT/BST	Multi-Port of Call Time Indicator	Small	<1
PT_b/BST = PRT/BST	Port Time Indicator (based on Berth Time)	Small	<1
PT_p/BST = PLT/BST	Port Time Indicator (based on Pilot Time)	Small	<1

BST's standardized performance measures would provide extensive multidimensional (internal and industry-wide) comparisons and analytical tools for better understanding of VT and for better research. This strategic average and marginal analysis is an input in firms': planning, investments, containership utilization, industry structure, containership operations, deployment of containership by size, containership selection, containership cascading, port rotation or addition, alliance formation or abolition, routing, port of call performance evaluation, and more. Comparisons are important for the analysis of each voyage segment to its past voyage, other segments on the same voyage, between voyages and other voyages. Moreover, some of the indicators could be further normalized and studied via models by incorporating, for example, the number of ports of call, the number of vessels or the number of containers to provide additional insights and comparisons. In general, most indicators are coincidental; some might be leading or lagging, depending on the data used.

3.2.2 Intermediate Ports of Call Transit Time (IPTT)

Intermediate ports of call are several ports in a voyage *excluding* the two farthest ports in the service loop, usually the O-D. IPTT is **defined** as the sum of the vessel transit times off the

BST course serving the intermediate ports of call in a voyage. From equation 2, IPTT is

$$IPTT = VT - (PT + BST + HWT) \quad (4)$$

IPTT in a multiport operation is inevitable. Getting off the BST course calling intermediate ports is the cause for the additional VT and costs, which makes IPTT the most important opportunity cost segment in the VT (equation 2). The larger the number of ports of call in a service loop, the larger the IPTT. Knowing the IPTT is vital when evaluating the tradeoffs between the advantages of economies of scale at sea and the disadvantages of the increase of overall transit time in terms of VTE.

IPTT data is presently not available in the public domain, but it can be estimated. IPTT data collection starts at voyage planning by identifying the location where the containership changes course off the BST course in order to make each intermediate port of call and where the vessel gets back on the BST course after departing the port. The data is recorded in the vessel voyage plan and voyage logbook during the voyage.

IPTT data is a core tool in the vessel's operation allocation of time in a firm's voyage plan per ship. There are two approaches to IPTT planning:

- **First best**. A containership operation is using time optimally when the number of ports of call is equal to an SS operating system or <u>first best</u> when IPTT = 0. An SS maximizes containership utilization if the vessel is also fully loaded. SS for large containerships is frequently unattainable.
- **Second best**. Presently, large containerships are deployed on long routes calling numerous ports while partially loaded when serving some intermediate ports. Since the "first best" option is generally not attainable for large containerships, shipping lines (or alliances) resort to the <u>second best</u>, seeking a minimal number of ports of call, thus keeping IPTT low

in terms of time and cost. Therefore, the decision-variables to minimize the number of ports of call in the operation system should be a part of the IPTT analysis.

3.2.3 Intermediate Port of Call Transit Time (IPTT/BST) Performance Ratio

The relative amount of time to call the intermediate ports of call is the ratio IPTT/BST. IPTT/BST is a controlled opportunity cost of time of getting off the BST course. It is controlled because the operator plans calling multiple ports in a voyage recognizing the cost in time. This ratio is an important indicator of the utilization of time of a vessel's overall operations because the smaller the ratio, the more efficient the overall containership utilization of time. The larger the number of ports of call, the smaller the number of annual containership's voyages.

The IPTT/BST ratio measures the opportunity cost of the multiple ports of call's impact on VT and therefore revenues. The ratio is an important strategic indicator when reviewing the multiport operation system, including the optimal number of ports of call (second best above).

3.2.4 Harbor Waiting Time (HWT)

Harbor waiting time is **defined** as the amount of time a vessel arriving at the port waits in the harbor (anchorage/mooring time) before berthing, for example, when the berth is not available or when a containership arrives ahead of schedule; otherwise, HWT = 0. Arrival time and the tie-up time are recorded in the vessel logbook. Presently firms record the HWT as a part of PT or ST.

3.2.5 Harbor Waiting Time (HWT/BST) Performance Indicator

The harbor waiting time ratio measures the amount of time the containership is **idle**. HWT is usually an uncontrolled opportunity cost segment of the voyage because the waiting is subject to local circumstances. This ratio should be zero (HWT/BST = 0) when virtual arrival or slow steaming is exercised. Excessive HWT is economically damaging to a firm. There is no HWT data in the public domain.

Idle time might also be planned as a part of the liner service schedule to maintain schedule integrity. For example, a weekly liner service could include a planned buffer of time to maintain schedule integrity for reasons of being off schedule in an earlier port, port congestion, strikes, weather conditions and others. In either case, each time this ratio is positive, especially when persistently so, a review of cause should be initiated.

3.2.6 Vessel Total Opportunity Cost of Time [(IPTT + HWT)/BST] Performance Ratio

The containership total opportunity cost of time ratio [(IPTT + HWT)/BST] is an indicator of the voyage's efficient use of time, including for schedule integrity (see above). This segment of time, the combined forced and unforced opportunity costs of time, in a multiport of call voyage is inevitable and is critical to quantify. Therefore, should HWT = 0 then the slack time is generated only by IPTT.

3.2.7 Sea Time (ST)

Sea time is **defined** as the total amount of time a vessel spends at sea. It is a major part of the VT (Equation 5).

$$ST = VT - PT = BST + IPTT + HWT \tag{5}$$

We note ST for an SS and ST for a multiple port of call service (IPTT).

- <u>Shuttle service</u>. The simplest voyage is an SS between two ports (IPTT = 0 and HWT = 0). Therefore, ST = VT – PT = BST. ST is simple to calculate/obtain because the voyage segments of time (VT and PT) are recorded in the vessel's logbook, the port, and the firm. This figure might differ by firms, depending on how HWT is recorded, as part of ST or PT.

- Multiple ports of call service time (IPTT > 0). IPTT complicates the voyage ST determination because a liner service calling multiple ports acquires IPTT time; the amount depends on the number of ports of call in the voyage. Furthermore, as before, this figure might differ, depending on how a firm records HWT, as part of ST or PT.

3.2.8 Sea Time (ST/BST) Performance Indicator

The ST ratio (ST/BST) provides new insight to the overall voyage performance. A containership operator of multiple ports of call has an additional cost of time quantified by [(ST/BST) – 1], which captures the ST beyond an SS operation. Firms should develop tools and performance-measures including performance-targets to monitor their operations and their schedule integrity using the ST/BST ratio. Furthermore, firms could opt analysis links with the number of ports of call in a loop, vessel size, number of vessels in the service, port rotation, and more. This analysis would be key in service improvement and better containership utilization.

3.2.9 Voyage Time (VT/BST) Performance Indicator

The VT performance ratio (VT/BST) enhances the understanding of the entire VT. This statistic should be similar in every voyage of the same route, the same number of ports of call and a similar number of containers handled. The expected similarity is because a liner service is scheduled weekly for a given amount of time, even though the distribution of VT between BST and IPTT + HWT differs. Deviation from expectations would be examined for cause, which could be due to planning, weather conditions or others.

3.2.10 Multi-Port of Call Time (MPCT)

Multi-Port of Call Time (MPCT) is **defined** as VT spent on other than the BST course (equation 6).

$$MPCT = VT - BST = IPTT + HWT + PT \tag{6}$$

MPCT should be obtained only for intermediate ports, not including the first and last ports because they are a part of the SS service as well. In an SS (IPTT = 0 and HWT = 0) MPCT is equal to PT. However, if MPCT is larger than PT, it could indicate that IPTT > 0 and/or HWT > 0.

3.2.11 Multi-Port of Call Time (MPCT/BST) Performance Indicator

With an increase in containership size, an increase in the number of ports of call, and an increase in the number of vessels in the same loop, to maintain schedule integrity, the MPCT/BST ratio is expected to increase. The MPCT/BST ratio is expected to have a small standard deviation for the same voyage loops with the same number of vessels and ports of call and a similar number of discharges and loads of containers. Normalizing the ratio by tracking the number of ports of call, the number of ships and the number of containers, the outcome links the ratio to containership size, which can be further used for port economies of scale analysis.

3.2.12 Port Time (PT)

PT is an important segment of the port of call in determining ST. The two methods of PT determination, Port Berth Time (PRT) and Port Pilotage Time (PLT), provide different insights into the economic use of PT.

3.2.13 Port Berth Time (PRT)

Port berth time (PRT) is **defined** as the amount of time a containership stays at the port from berthing to unberthing. This data is recorded in every port and in the vessel's logbook. Therefore, the port berth time is (equation 7):

$$PRT = VT - ST \tag{7}$$

PRT is instrumental in tracking a port's performance in terms of port efficiency.

3.2.14 Pilot-to-Pilot Port Time (PLT)

Pilot-to-Pilot Port Time (PLT) is **defined** as the amount of time a containership stays at the harbor from the time the inbound pilotage service starts to the time the outbound pilotage service ends. Thus, PLT data contains the PRT data. Piloting a vessel inbound and outbound to its berth starts and ends in the harbor or at sea some distance away from the port. In and out piloting times are recorded by the pilots' association and in the vessel's logbook. Obviously, the difference between PLT and PRT is the net piloting time. The port pilotage time is (equation 8):

$$PLT = VT - ST \tag{8}$$

As before, PLT is instrumental in tracking port performance.

3.2.15 Port Berth Time (PRT/BST) and/or Pilot Time (PLT/BST) Performance Indicators

The PRT/BST ratio and/or PLT/BST ratio is the amount of time a containership spends in the port with respect to BST. This ratio:

- Provides the average time in port (PRT/BST/(number of ports) or PLT/BST/(number of ports)), which shows the deviation from predetermined standards or agreements.
- Is expected to be similar from one port call to another under similar conditions; that is,

vessel travel speed, distance from pilot to berth, number of containers to be exchanged, and terminal productivity.

- Would change with changes of terminal productivity or the number of containers handled per port of call.
- Can be further subdivided by the number of containers or normalized [(PRT/BST)/(number of containers) or PLT/BST/(number of containers)] to determine the amount of time it takes to handle a container.
- Can be further analyzed for (PLT – PRT)/BST ratio to determine piloting impact on operations.

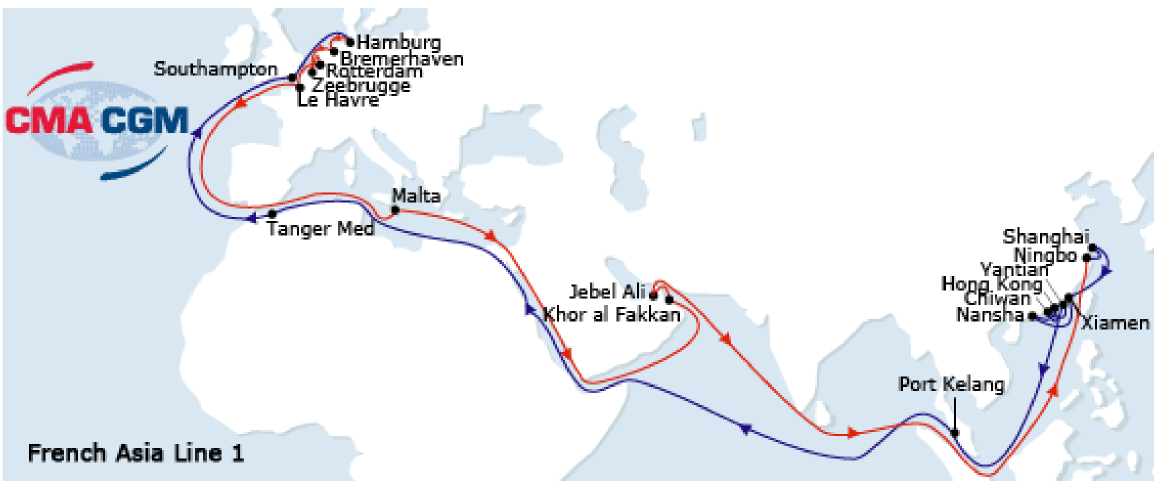
The data source for this analysis is voyage records (past and present). The analytical and practical use of the data is in tracking performance over time, including deviations from firms' operation targets.

<u>In summary</u>, the family of BST ratios/indicators are:

- New sound measures of the opportunity cost of time of calling multiple ports.
- Tracking tools for: operation evaluation (number of ports of call, routing, containership size mix, number of containers discharged and loaded per port, and others), standardizing services, comparing operations (by firm and across firms and alliances), research and more.
- Used to develop operation models and/or policy tools and targets to evaluate and optimize performance.
- Used to analyze incremental/marginal changes in operation-policy of adding a port or a vessel to the operation.
- Important in both absolute and relative value of time and as time changes.

4. Illustration

The illustration of a typical multiport operation uses the 2015 French-Asia Line 1's (FAL1) liner service between Shanghai, China and Hamburg, Germany; a 77-day voyage loop serving 18 ports of call (Figures 1 and 2 and Equations 1 and 2) (Guan et al., 2017). This service could also have a loop of 70 and 84 days. A one-way VT of 38.5 days and nine ports of call is used for illustration because voyage routes differ. Figure 2, Equation 1 shows the contemporary FAL1 one-way ST and PT of 29.5 and 9 days, respectively. For best results hours should be used, not days.



Source: https://thecruisepeople.wordpress.com/2012/02/14/french-asia-line-1-brings-the-worlds-largest-passenger-carrying-container-ships-to-the-southampton-far-east-trade/

Figure 1: Sea time from Shanghai to Hamburg (French-Asia Line 1)

	Loop FAL1: VT = 38.5 days (100%) (9 ports of call)			
Equation (1)	ST = 29.5 days (76.6%)			PT = 9 (23.4%)
Equation (2a)	BST = 23.5 days (61%)	HWT	IPTT	PT = 9 (23.4%)
Equation (2b)	BST = 23.5 days (61%)	MPCT = 15 days (39%)		

Figure 2: The segments of a containership's one-way voyage time (Example of FAL1)

Applying the new BST methodology, the one-way segments developed above are estimated as follows:

- Baseline Sea Time (BST). The SS voyage distance of the FAL1 route is 11,305 NM (https://sea-distances.org/, 2017). Assuming 20 knots average voyage speed, the BST one-way voyage is 565.25 hours (23.5 days) (Figure 2, Equations 2a&b). This voyage's BST statistic is always the same.
- Multi-Port of Call Time (MPCT). The MPCT voyage (Figure 2) is 15 days (38.5 - 23.5, includes the intermediate and first and last ports because there is no data per port available in the public domain).
- Intermediate Ports of Call Transit Time (IPTT). The voyage of nine ports of call is estimated at 6 days (Equation 4) [VT (38.5 days) - BST (23.5 days) - PT (9 days, assuming PT of about one day for each intermediate port of call) - HWT (0 days)].
- Port Time (PT)
    - Port Berth Time (PRT). For example, when a containership is berthed at 1500 hours and unberthed at 1500 hours the following day, the total stay at the berth (or port) is 24 hours.
    - Pilot-to-Pilot Port Time (PLT). For the PRT aforementioned containership, if the inbound pilot boards the vessel at 1400 hours and the outbound pilot departs at 1600 hours the following day, the containership's total stay in the port (PLT) is 26 hours. The two additional hours are the difference between PLT and PRT.

Applying the ratios/indicators to the aforementioned above, we obtain the following:

- IPTT/BST ratio. The ratio of the estimated 6 IPTT days to 23.5 BST days is 0.255 (6/23.5) (Table 2). This ratio is a **constant,** indicating that the liner service spends 25.5% accessing intermediate ports of call compared to an SS (BST).

The one-way liner services (FAL1) has been observed having a VT of 35, 38.5 and 42 days. Currently, with the VT as a base, the 6-IPTT days generates IPTT/VT ratios of 0.171 (6/35), 0.156 (6/38.5) and 0.143 (6/42), respectively (Table 2). Likewise, when comparing IPTT to ST as a base, the IPTT/ST ratios are 0.235 (6/25.5), 0.203 (6/29.5) and 0.185 (6/32.5), respectively (Table 2). Thus, what should be the comparison base: BST, VT, or ST? The comparison to the VT and ST figures differs widely and offers obscure results. Furthermore, any comparison (MPCT, PRT, PLT, etc.) to VT and/or ST is unreliable for the same reasons and should not be attained. <u>BST fixes the obscurity. There is only one result **0.255,** because it is based on distance and operating speed</u>. BST standardizes the analysis and overcomes the present unreliable approach for comparison and analysis.

Table 2: The estimated 6-IPTT-day ratios with BST, ST, and VT

Ratios	**BST (Days)**	**ST range (Days)**			**VT range (Days)**		
	23.5	**25.5**	**29.5**	**32.5**	**35**	**38.5**	**42**
IPTT/BST	**0.255**						
IPTT/ST		0.235	0.203	0.185			
IPTT/VT					0.171	0.156	0.143

Applying the ratios/indicators aforementioned to the FAL1 one-way liner service, we obtain the following:

- <u>Sea Time (ST/BST) ratio</u>. The ST/BST ratio of the 29.5 ST days of liner service is 1.255 (29.5/23.5), indicating that ST (or IPTT + HWT) is 25.5% larger than BST; that is, the containerships spend 25.5% more time at sea compared to an SS. Moreover, when applied to voyage ST of 25.5 and 32.5 days, the ratios are 1.085 (25.5/23.5) and 1.383 (32.5/23.5), respectively (Table 2).

- Voyage Time (VT/BST) ratio. The VT/BST ratio of the liner service of 38.5 days is 1.638 (38.5/23.5), indicating that 68.3% of the VT is for other than SS, where the cargo takes 63.8% additional time from first to last port. Furthermore, when applied to voyage ST of 35 and 42 days, the ratios are 1.489 and 1.787, respectively.
- Multi-Port of Call Time (MPCT/BST) ratio. The MPCT/BST ratio of the liner service shows a ratio of 0.638. This is the reciprocal of VT/BST, with the same interpretation.
- Port Time (PT/BST) ratios. The voyage records PT/BST ratio of 9 day as 0.383 (9/23.5). The ratio offers a reliable BST comparison base for analysis.

In short, the ratios/indicators illustrated above provide new consistent and reliable tools for comparison and analysis.

5. Research illustrations using BST

The BST concept and methodology enable new research and analysis opportunities on voyage use of time in the liner shipping business to settle important theoretical and practical questions. For example, the research of the cause of diseconomies of scale in the port, using BST, can now, not only pinpoint the cause via segments, but also be standardized for study and comparison. The research of the impact of large containerships and the number of ports of call per voyage on VT, ST and PT is now also standardized. The research of the economies of scale at sea and at the port associated with changes in vessel size and in the number of ports of call, will benefit greatly from using the new data and indicators, i.e., the research will pinpoint the exact reasons that contribute to both, which is a new result.

Seeking complex answers, researchers and analysts could build multivariate BST models based on standardized data. The models will explain the sensitivity of any one of the dependent variables, such as voyage time, sea time, port time, and multiport of call time, by any one or a multiple of independent variables, such as: sea time, port time (port berth time and/or pilot-to-pilot port time), intermediate port of call transit time, multiport of call time, harbor waiting time, number of ports of call, vessel size, cascading, transit distance, transit speed, investments in vessels, income generated per port or per voyage, number of containers D&L per port, and others. Other research using BST segments addressing vessel operation and the business of liner shipping could include variables that: explain return on investments, compare different global regions (Europe, US, Asia, etc.), analyze trip cost per BST segment, and impact on Just-in-Time or slow steaming or virtual arrival.

Descriptive statistics can be used to compare, among other variables, vessel performance, routes, port rotations, loading rates, both internally over time or across firms and group of firms operating, for example, in alliances. The analysis can be performed and compared per voyage or in the aggregate. Thus, the analysis directly and indirectly contributes to better vessel and fleet utilization and management, fleet deployment, investments in fleets, scrapping schedules, and responding to shipper needs.

The standardized data obtained and analyzed can answer (small sample): What is the optimal number of ports of call? What is the optimal vessel size per route? What is the opportunity cost of a long voyage with multiple ports of call? Does the latter change due to vessel size and number of containers D&L? What is the breakeven of containership size between large containerships' economies of scale and port diseconomies of scale and/or by port? These answers provide important insights into the liner service industry's performance that is obtainable due to BST.

6. Conclusion and recommendations

BST is a new methodology developed to standardize containerships' voyage time efficiency and performance measures. BST, based on distance and average speed, is a constant per port pair route. BST is based on simple ratios and indicators that serve as standard baseline tools for comparisons of VT segments (ST, IPTT, MPCT, HWT, PRT and PLT) internally and between operators.

Obviously, to achieve the analysis and comparisons, data sharing and its challenges are required.

BST tools shade a new light and offer new insight into service performance and tradeoffs between transit times of ports of call in a service loop. BST shows the opportunity cost of time spent going to, from and within intermediate ports of call and enhances the economic understanding of the voyage segments. Continuous monitoring of the new measures provides a better understanding of firm and industry performances and a good analytical tool for decision-making in the private and public sectors, leading to optimal services.

BST tools provide an insight to the increased economies of scale and decreased voyage time efficiency due to the increasing vessel sizes. Ratios/indicators derived from BSTs identify and quantify critical information regarding service loop characteristics of time efficiency and potential implications for both the shipping lines and shippers.

The results obtained from the illustration are consistent with expectations. The illustration demonstrates that BST and its derived ratios/indicators are simple to obtain, easy to understand and therefore practical to use. For example, the illustration (a 77-day liner service with 18 ports of call) shows that under the current multiple ports of call service loop operation, the voyage ST is

25.5% longer when comparing to an SS base. The cargo between the first and last ports of call spends an additional 63.8% of the VT staying on board when compared to an SS. The industry is aware of the opportunity cost of multiple ports of call, and now it can also measure it.

BST is a new standardized method that offers quantifiable and reliable data for new analysis and enhanced insights for planning the number of port calls, port rotation, size of vessels per route, the number of vessels deployed per route, and vessel utilization. For cargo owners/shippers, BST provides a yardstick to compare route service offerings by shipping lines and route tradeoff implications for their cargo. Moreover, for researchers and analysts, the research results will be published in review journals and professional magazines enabling discussions and debate and the development of the best practice methods.

The BST ratios/indicators are new critical tools recommended for performance analysis by operators, researchers, analysts, firms, and stakeholders in both the public and private sectors. These new tools close an analytical gap and are recommended for determining the impact on: vessel deployment by size and route, port selection and rotation, the number of vessels per loop and voyage duration, economies of scale at sea and in port, and market competition. These new indicators could be used for: contract negotiation, operation time guarantees, benchmark developments, asset utilization, investment risk assessment, breakeven analysis of the optimal number of ports of call, indirect measure of diseconomies of scale of large containership voyages, input in determining the need of new large ship building, and the cost of large containerships on ports. Finally, the new ratios/indicators offer new research opportunities to better understand the liner service industry performance internally and externally and its implications.

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