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Containership Bay Size and Spreader Technology's Impact on Container Moves per Lift

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Research Objective

Analyze the discharge and load (D&L) time of a containership bay, focusing on the relationship between containership bay size and gantry crane productivity.

The research is based on the Bay Time factor impact on containership port time, developed by the authors. This is the key tool to the understanding of the need for container terminal investments in new D&L technology.

Containership Size

***Regina Maersk* Dimensions**

Carrying capacity: 6,418 TEU

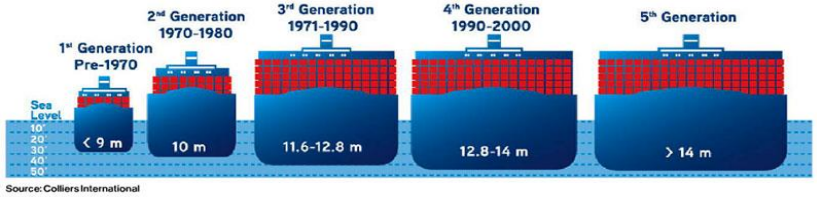
Length: 1,044ft (318.2m)

Beam: 141ft (42.8m)

Draft: 47ft (14.2m)

Containers across: 17

Year: 1996



***The Ever Ace* Dimensions**

Carrying capacity: 23,992 TEU

Length: 1,300ft (400m)

Beam: 202ft (61.5m)

Draft: 47.6ft (14.5m)

Containers across: 24

Year: 2021

Containership Bay Time impact on port time

Summary of containership class and main characteristics

Containership size	TEU range		Containership characteristics (meters)						(1)/ (2)*
	TEU	TEU	LOA	Beam (1)	Draft	Tiers on deck	Tiers below deck	Rows (2)	
Panamax	3,000	3,400	250	32	12.5	5	6	13	2.46
Panamax Max	3,400	4,500	290	32	12.5	6	8	13	2.46
Post Panamax	4,000	5,000	285	40	13	5	9	15	2.67
Post Panamax Plus	6,000	8,000	300	43	14.5	6	9	17	2.53
New Panamax		12,500	366	49	15.2	6	10	20	2.45
Post New Panamax		15,000	397	56	15.5	8	10	22	2.55
Triple E		18,000	400	59	15.5	8	10	23	2.57

*This data was not part of the source.
Source: http://www.skyscrapercity.com/showthread.php?t=1514993&page=18

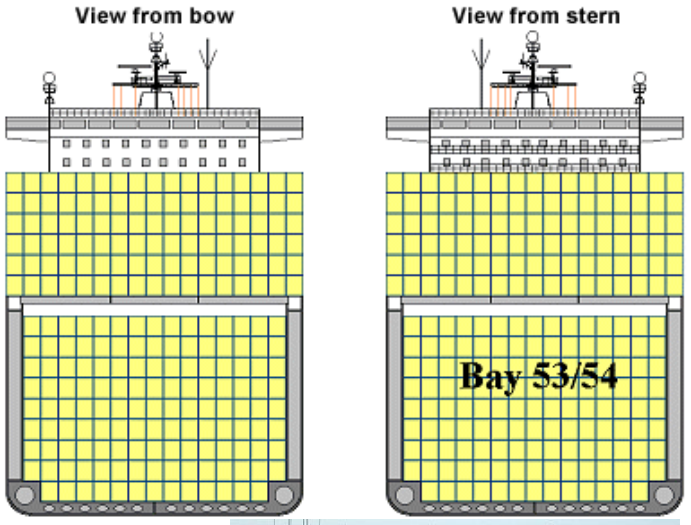
Containership Size Impacts

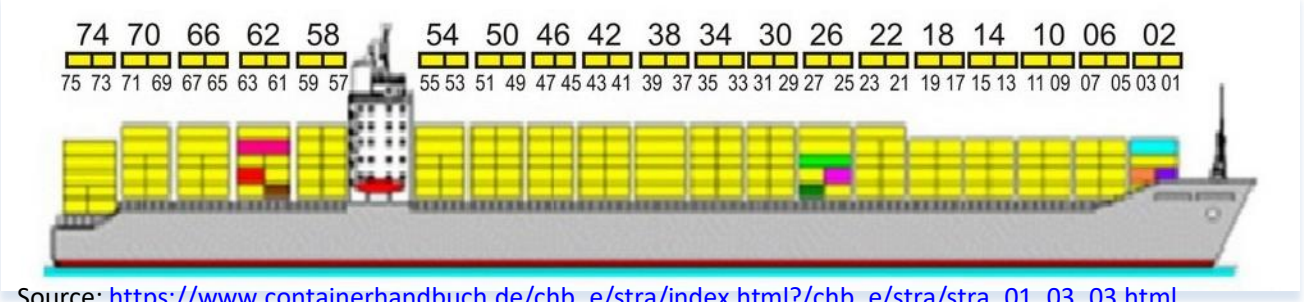
- Economies of scale at sea
- Diseconomies of scale in the port
  - The cargo bay size has been getting much larger.
  - The number of containers a gantry crane handles in a cargo bay is much greater.

A Cargo Bay is defined as a compartment onboard a containership that stores containers.

ABC's of Containership Stowage System

- A containership's stowage system is based on a bay-row-tier system. "Usually a bay is divided vertically by hatches into two sections, below deck and on deck…. every bay contains a set of slots. Each slot is uniquely identified by three indices:
  - bay, that gives the bay it is located in;
  - row, that gives its position relative to the vertical section of the corresponding bay (counted from the center to outside);
  - tier, that gives its position relative to the horizontal section of the corresponding bay (counted from the bottom to the top)." Fan (2010)

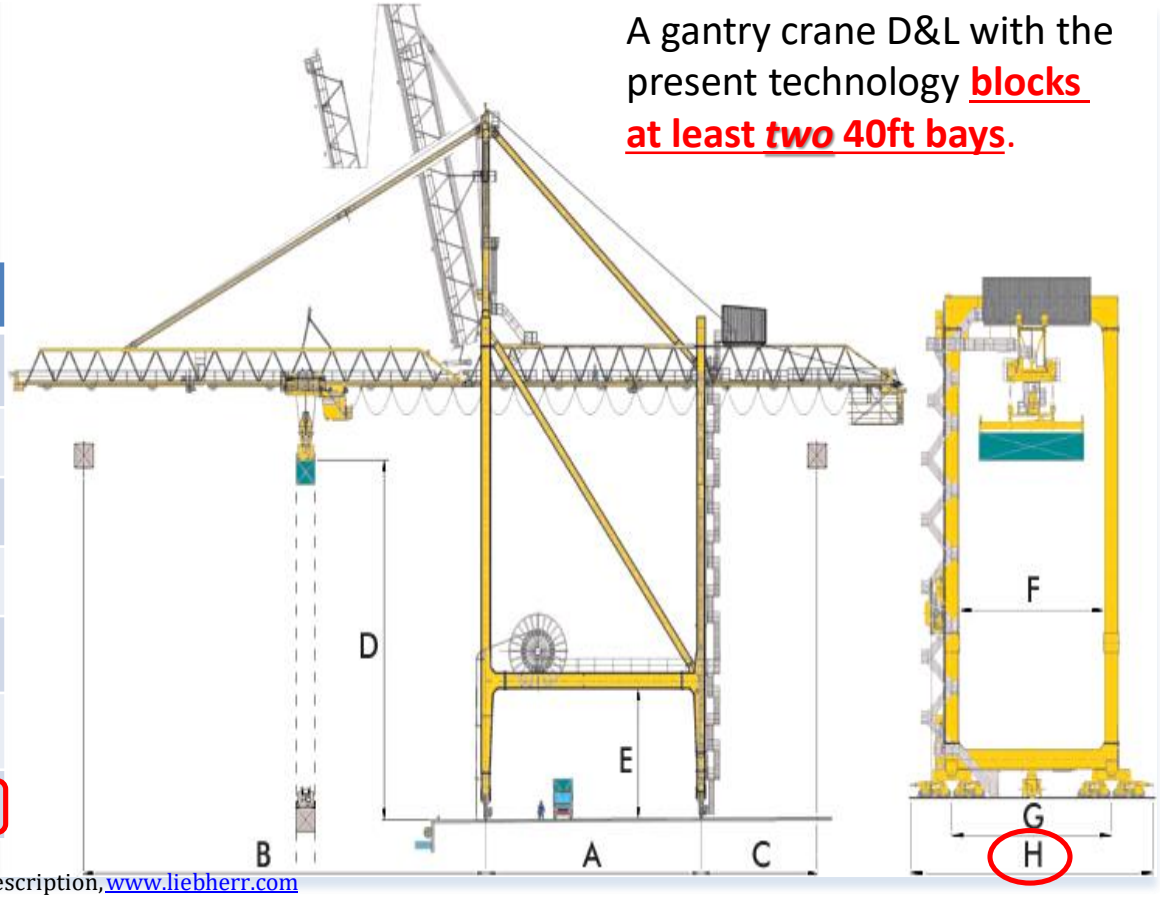




Source: https://www.containerhandbuch.de/chb_e/stra/index.html?/chb_e/stra/stra_01_03_03.html

Gantry Crane Characteristics

Legend	Length (meters)
A: Gantry Span or Gauge	15.0 – 50.0
B: Outreach	30.0 – 60.0
C: Backreach	0.0 – 30.0
D: Lift Height	20.0 – 55.0
E: Clearance under Sill Beam	12.0 – 18.0
G: Travel Wheel Gauge	18.2 (depending on wheel loads)
H: Buffer to Buffer	27.0 (88.7 feet)



A gantry crane D&L with the present technology **blocks at least *two* 40ft bays**.

Source: Liebherr Ship-to-Shore Container Gantry Technical Description, www.liebherr.com

Containership Bay Time impact on port time

Crane Productivity

Crane productivity (**lifts** per hour per crane)

Issues impacting crane productivity:

- Technology
- Operators' skills
- Container location
- Gross and net output
- Different ports and terminals
- Management
- Productivity range (reporting format – not standardized)

Definitions

Bay Time

- The amount of time (hours) it takes to D&L a fully loaded cargo bay of a containership.

$$\text{Bay time (hours)} = \frac{Number\ of\ containers\ stowed\ in\ a\ bay\ (20ft\ \&\ 40ft)}{Crane\ productivity\ (\boldsymbol{lifts\ per\ hour})}$$

Berth time

- The amount of time between vessel docking (berthing) and undocking (un-berthing), i.e., also a function of D&Ling.

*Estimated **minimum bay time (hours)** for **D&L** of the largest bay by containership size (**one bay**)*

Container ship class	Slots per bay	Boxes for D&L*	Productivity level (P) (lifts per hour)								
			30	35	40	45	50	55	60	70	80
Panamax	131	367	12.2	10.5	9.2	8.2	7.3	6.7	6.1	5.2	4.6
Panamax Max	168	470	15.7	13.4	11.8	10.5	9.4	8.6	7.8	6.7	5.9
Post Panamax	198	554	18.5	15.8	13.9	12.3	11.1	10.1	9.2	7.9	6.9
Post Panamax Plus	241	675	22.5	19.3	16.9	15.0	13.5	12.3	11.2	9.6	8.4
New Panamax	306	857	28.6	24.5	21.4	19.0	17.1	15.6	14.3	12.2	10.7
Post New Panamax	378	1058	35.3	30.2	26.5	23.5	21.2	19.2	17.6	15.1	13.2
Triple E	396	1109	37.0	31.7	27.7	24.6	22.2	20.2	18.5	15.8	13.9
Next Generation	436	1221	40.7	34.9	30.5	27.1	24.4	22.2	20.3	17.4	15.3

*The number of 20ft and 40ft containers D&L'd are at a ratio of 40% to 60%, respectively. For example, the Panamax has 131 slots of 40ft per bay, which is 262 TEUs, of which 40% are 20ft containers (104.8 containers) and 60% are 40ft containers (78.6 containers) for a total of 183.4 containers or 367 D&L'd containers.

Findings from estimates of bay time

For every increase in containership size by way of the beam (adding one row and one tier to the bay), **the average estimated D&L time for two bays increases by an average of 4.5 hours (standard deviation of 0.12) at any one of the productivity levels**. This is a very stable marginal cost of time.

There is an inherent increase in the diseconomies of scale at the port.

*The Relationship between Bay Size, Crane Productivity and Bay Time: **an analysis of time***

Case 1: Crane Productivity

- Optimum: when the number of cranes = number of cargo bays
  - Crane blocking 2 bays: Max cranes = number of cargo bays/2
- Crane productivity increases over time.

What is the required (or minimum) **crane productivity** to meet a **constant bay time?**

Case 2: Bay Time

- The larger the bay size (larger beam), the larger the minimum bay time (assuming constant crane productivity).
- A crane per bay minimizes berth time, **not bay time**.

What is the required (or minimum) **bay time** when **crane productivity is a constant?**

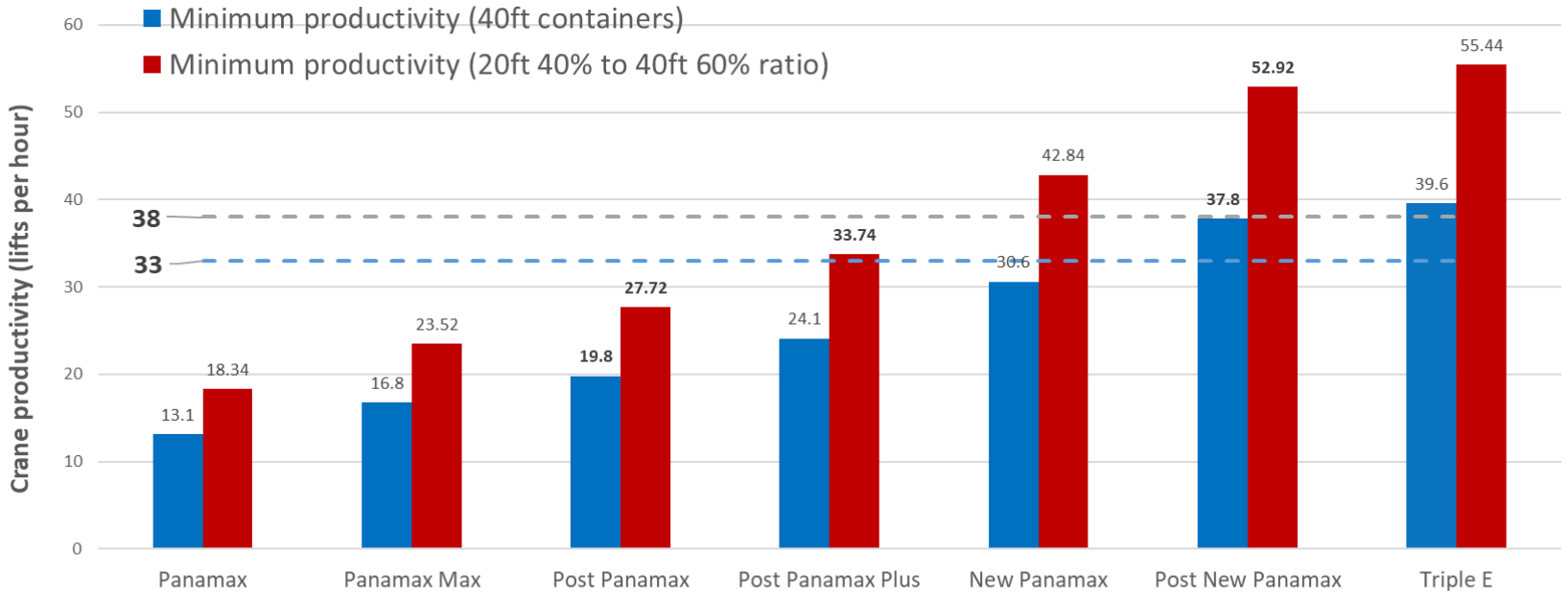
The timing of the two trends is not synchronized.

Case 1: ***Minimum crane productivity*** *(lifts per hour) to D&L a bay in 20 hours (constant bay time)*

Containership class	Number of 40ft containers to D&L	Minimum productivity (lifts/hour) (40ft containers)	Number of containers to D&L at 40% to 60% ratio*	Minimum productivity (lifts/hour) (40% to 60% ratio*)
Panamax	262	13.10	367	18.34
Panamax Max	336	16.80	470	23.52
Post Panamax	396	**19.80**	554	**27.72**
Post Panamax Plus	482	24.10	675	33.74
New Panamax	612	30.60	857	42.84
Post New Panamax	756	**37.80**	1058	**52.92**
Triple E	792	39.60	1109	55.44

*The number of 20ft and 40ft containers D&L'd are at a ratio of 40% to 60%, respectively.

Case 1: ***Minimum crane productivity*** *(lifts per hour) to D&L a bay in 20 hours (constant bay time)*



*Case 2. **Minimum bay time** (hours) to D&L at a **given** gantry crane output of 35 lifts per hour*

Containership class	Number of 40ft containers to D&L	Minimum bay time (hours) (40ft containers)	Number of containers to D&L at 40% to 60% ratio*	Minimum bay time (hours) (40% to 60% ratio*)
Panamax	262	7.5	367	10.5
Panamax Max	336	9.6	470	13.4
Post Panamax	396	11.3	554	15.8
Post Panamax Plus	482	13.8	675	19.3
New Panamax	612	17.5	857	24.5
Post New Panamax	756	**21.6**	1058	**30.2**
Triple E	792	22.6	1109	31.7

*The number of 20ft and 40ft containers D&L'd are at a ratio of 40% to 60%, respectively.

Bay slots and crane productivity changes over the last 20 years

Crane productivity in many ports increased from about 20 lifts an hour (Panamax generation) to about 38 lifts an hour (Triple E generation), a 90% increase (using Panamax as a base).

Bay carrying capacity for the same time and the same vessels increased by an estimated 202% (using Panamax as a base).

Are the trends moving towards conversion?

Bay slots and crane productivity over the last 20 years: sensitivity analysis

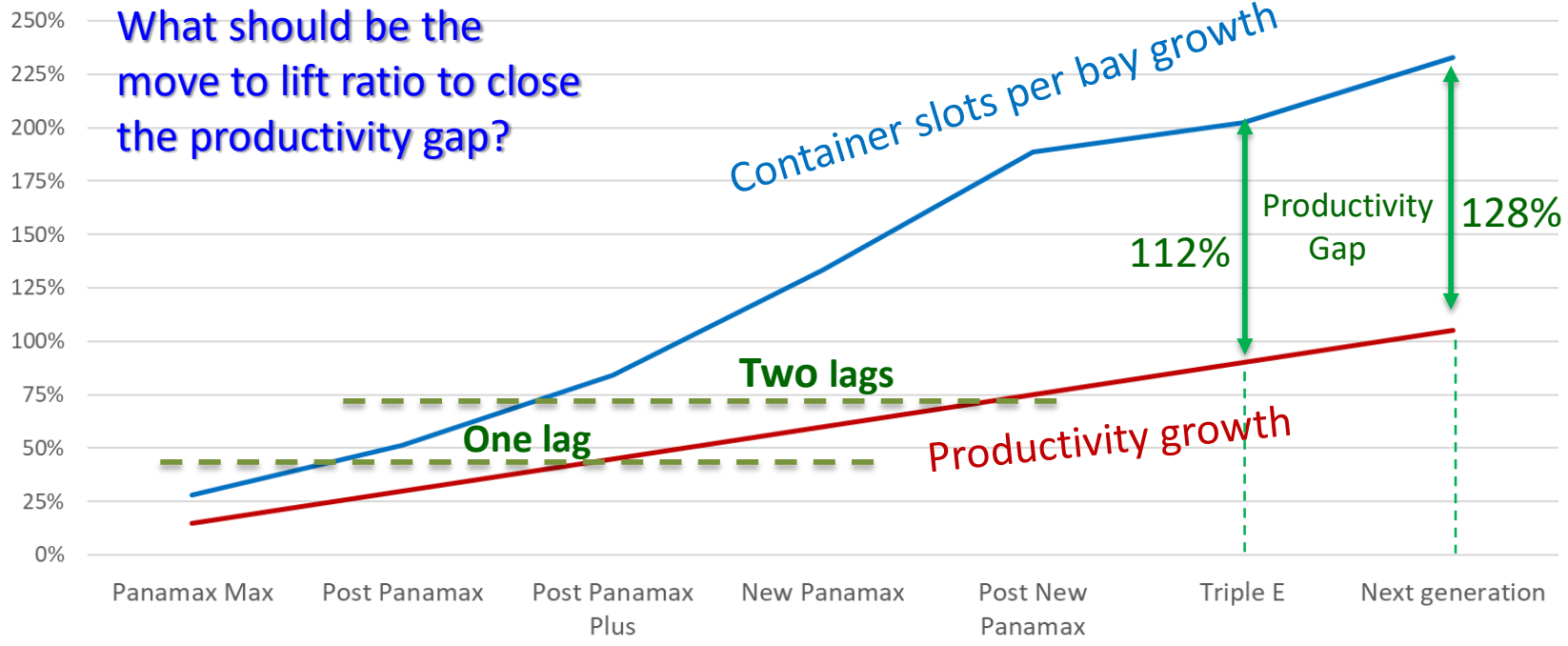
Crane productivity gap closure had an **estimated lag** of **at least one** containership class.

For the large ships the **lag** is **two containership classes or more**.

No Convergence

Vessel class	Number of 40ft slots per bay	Slots per bay growth (Panamax as base) (1)	Produc-tivity (lifts/ hour)	Productivity Growth (20 lifts/hour as base) (2)	Produc-tivity Gap (1)-(2)	Ratio (1)/(2) (3)	Ratio with one lag (4)	Ratio with two lags (5)
Panamax	131		20					
Panamax Max	168	28%	23	15%	13%	1.88		
Post Panamax	198	51%	26	30%	21%	1.70	**0.94**	
Post Panamax Plus	241	84%	29	45%	39%	1.87	**1.14**	0.63
New Panamax	306	134%	32	60%	74%	2.23	1.40	0.85
Post New Panamax	378	189%	35	75%	114%	2.51	1.78	**1.12**
Triple E	396	**202%**	38	**90%**	112%	2.25	2.09	1.48
Next generation	436	233%	41	105%	128%	2.32	1.93	1.80

Container slots per bay and productivity growth

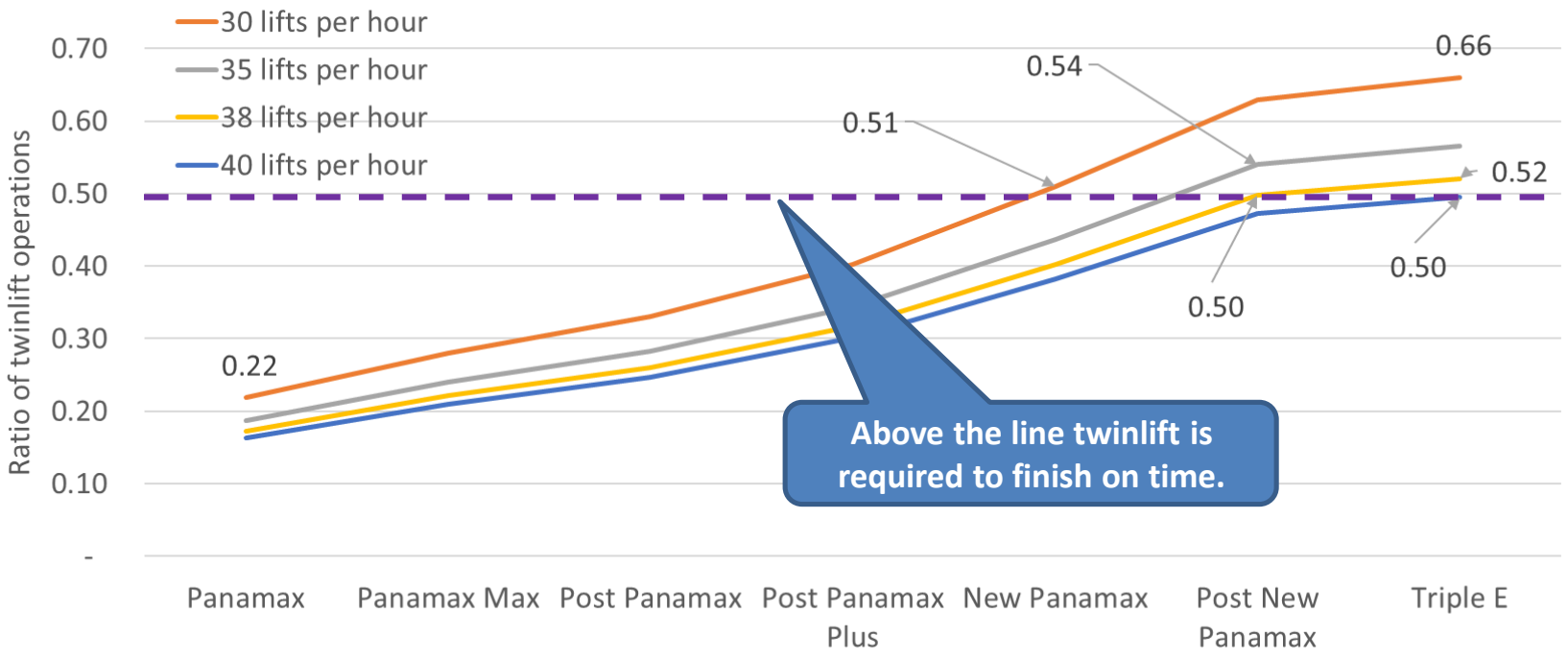


Gantry Crane Operation Characteristics

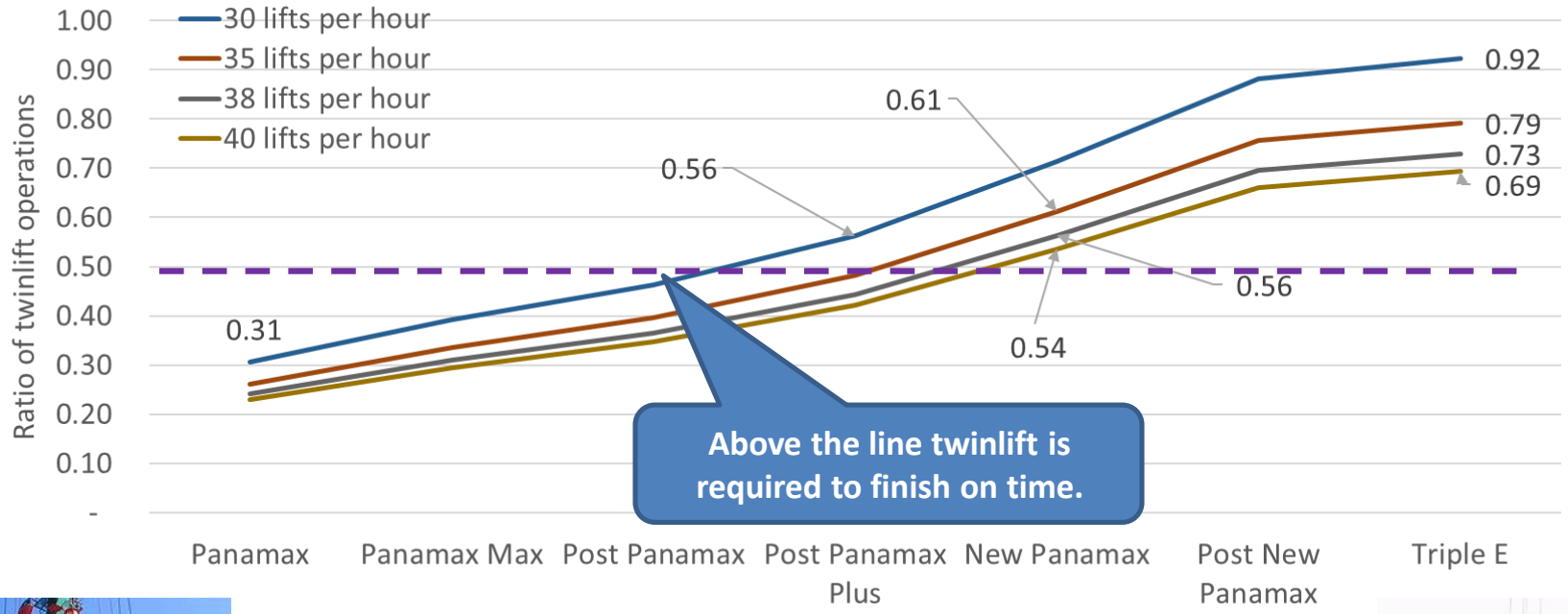
Gantry crane operations are measured in:

- ***The moves-per-lift ratio (r) = (M/L)***
  - Potential M = 1, 2, 3, 4, 6 moves per lift
  - r ≥ 1 [r = 1 same as L = M; **r > 1** indicates moving multiple containers per lift]
- **The *coefficient of utilization* (*t*)**
  - Operation productivity of D&Ling of multi-containers per lift was reported to be **70%** of one container per lift
- **The *coefficient of dual cycle* (*d*)**
  - Possible only below deck and not for all tiers
  - Increases overall D&L operations by **10%**

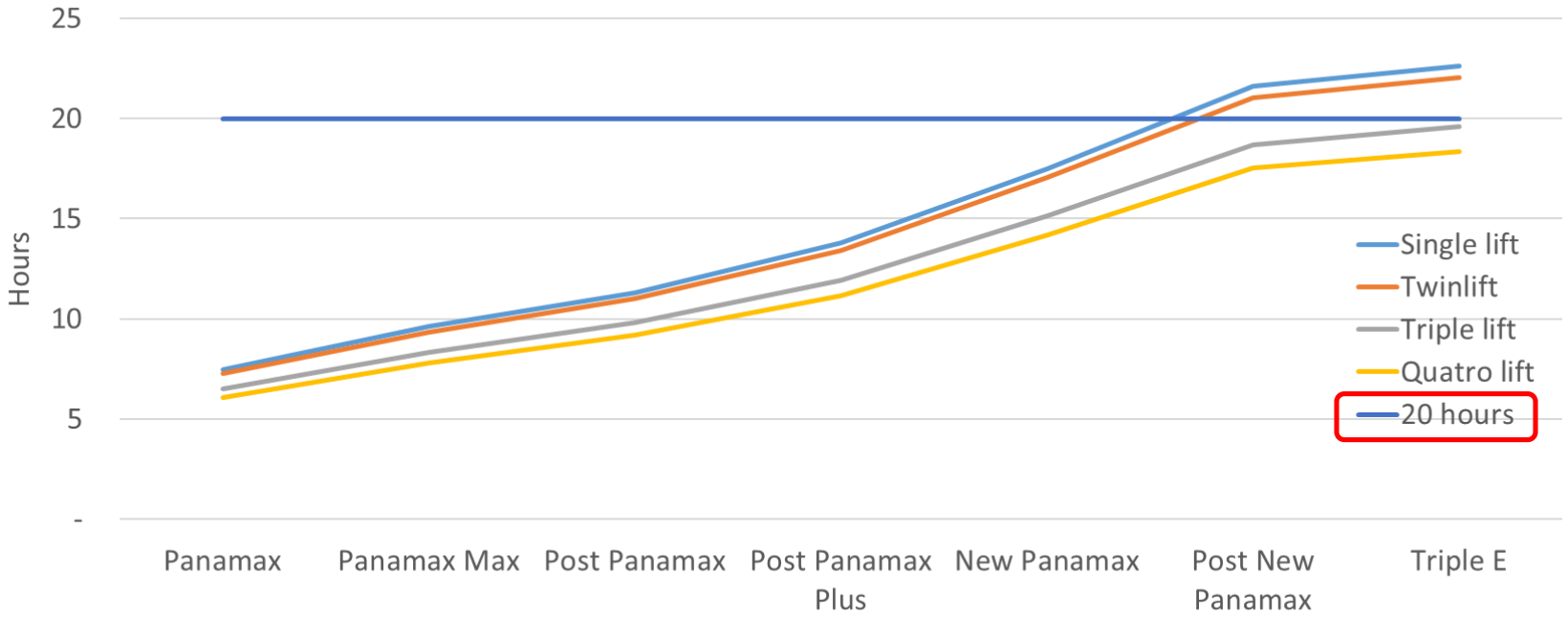
*Twinlift operation ratios for a **40ft container bay***



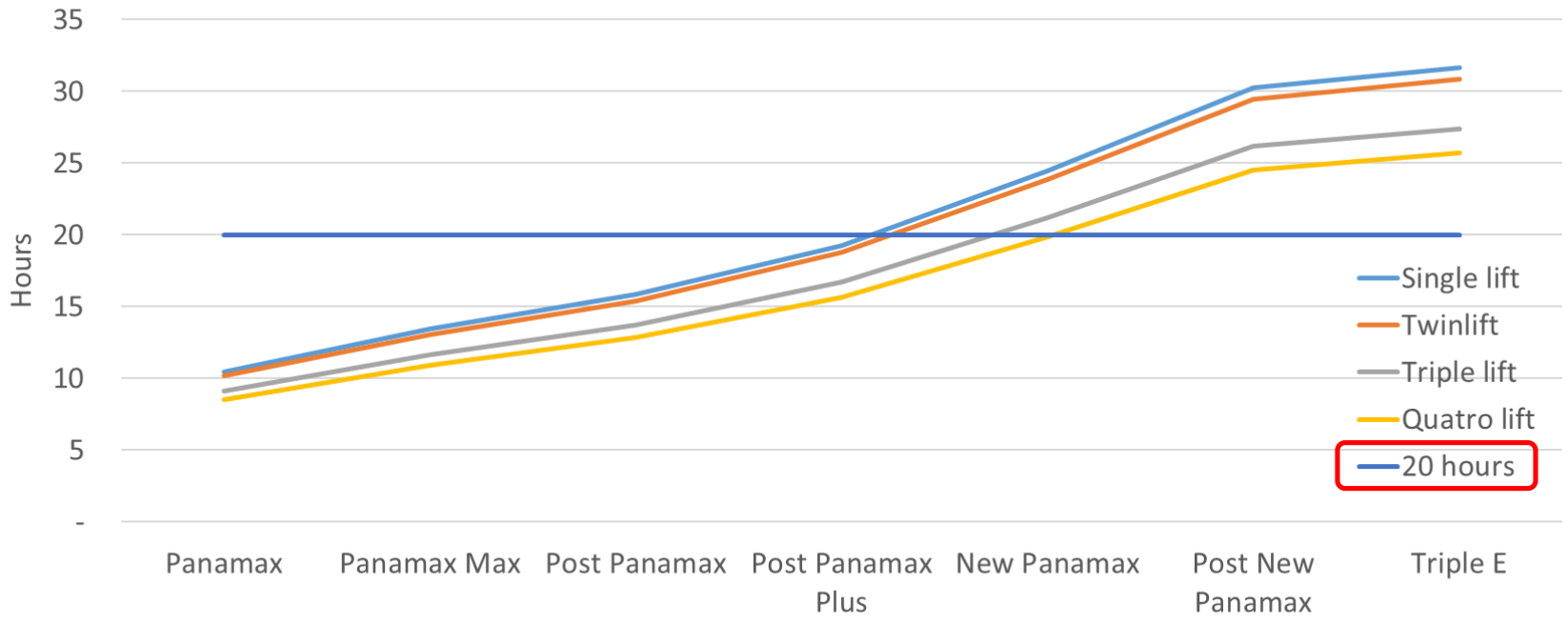
Twinlift operation ratios for a ***mixed bay*** *of 20ft and 40ft containers*



*Present D&L time of **40ft container bays** at 35 lifts per hour dual cycle and 70% productivity*



*Present D&L time of **mixed container bay** at 35 lifts per hour dual cycle and 70% productivity*



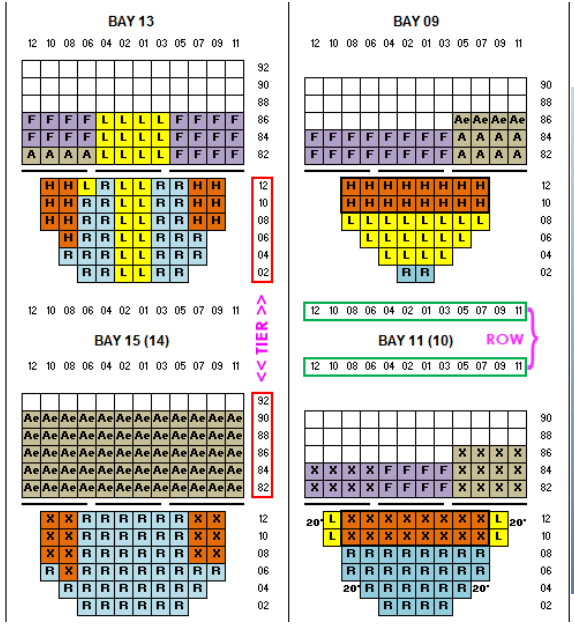
Challenges

The containership industry is expected to keep increasing beam size.

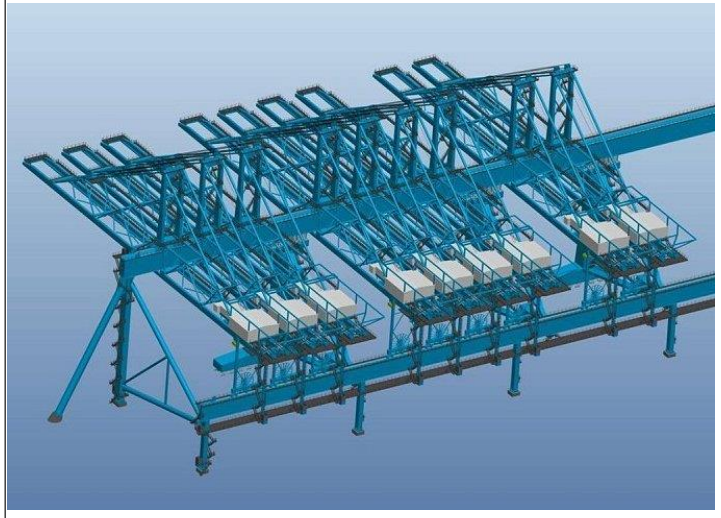
The solution to the challenges of the diseconomies of scale at the port is primarily the responsibility of the container port:

New Spreaders (port)

Stowing (ship owner/operator)



"Fastnet" (port)



Summary and Conclusions

- **Beam/bay size** is the most important factor determining **bay and berth time**.
- The higher the crane productivity, the shorter the bay time and consequently the berth time and port time.
- The inherent **diseconomies of scale** of large bays, due to the ports' lagged productivity adjustments, result in:
  - An increase in the number of ports of call per voyage for large containerships, i.e., a "new normal."
  - Stowage planners of large containerships avoiding a high concentration of cargo for the same port in adjacent bays and/or in one bay.
- **Solution**: Increase the crane productivity via **sophisticated spreaders** and the number of cranes.

Summary and Conclusions

As containership size has been growing, ports should decrease containership bay time and, therefore, berth time and ultimately port time by improving crane productivity and yard operations.



Q & A

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Book: Shmuel Z. Yahalom and Changqian Guan,
"Containership Bay Time: Impact on Port Time
Theory and Practice: A Handbook Approach," February 2023.