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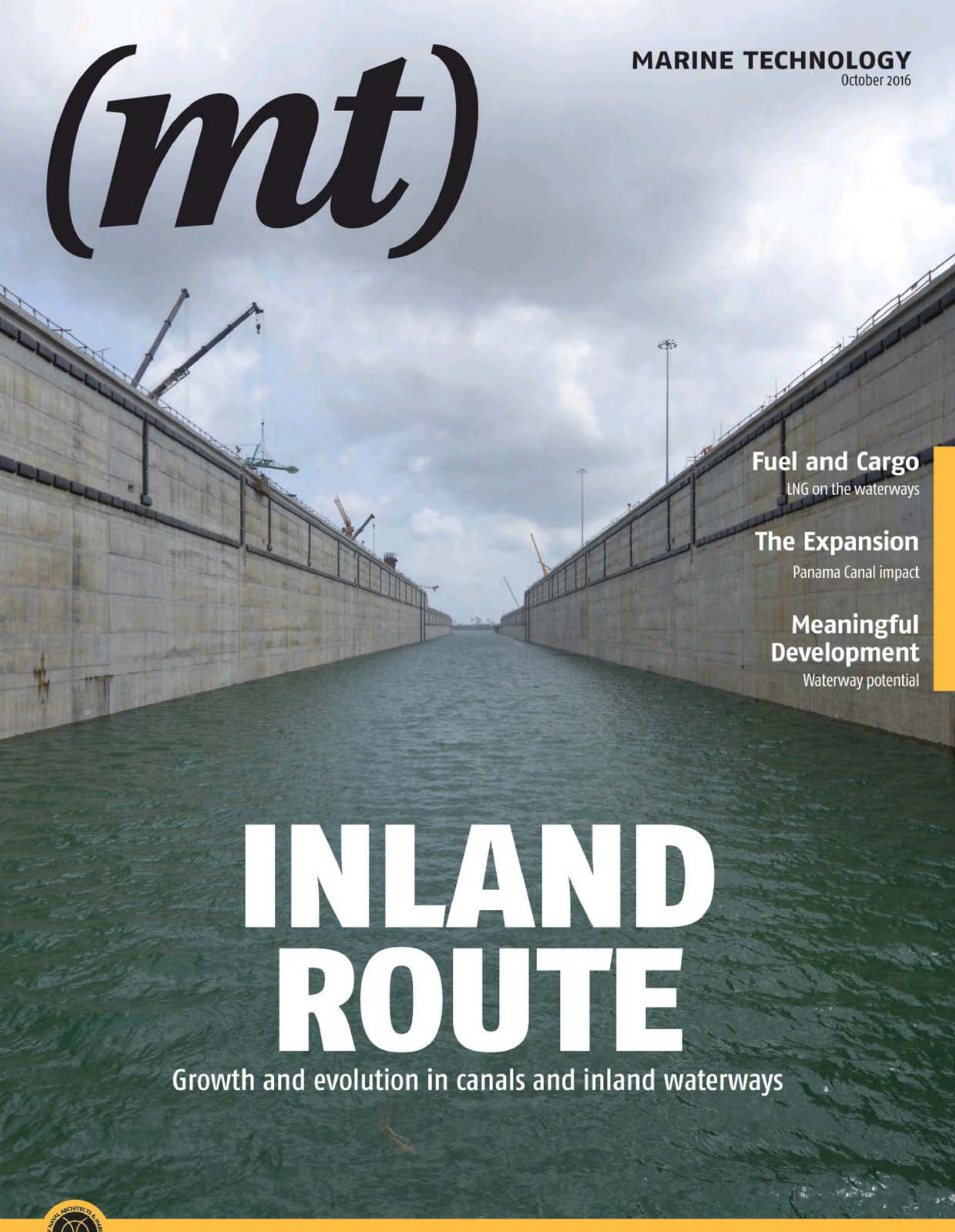
MARINE TECHNOLOGY
October 2016



Fuel and Cargo
LNG on the waterways

The Expansion
Panama Canal impact

Meaningful Development
Waterway potential

INLAND ROUTE

Growth and evolution in canals and inland waterways

A publication of SNAME

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(from the editorial board)

Expounding on Expansion

We have typically run a regionally-focused issue of *(mt)* each year in October or January. This year, rather than focusing on a specific region, our October issue explores the broader theme of canals and inland waterways throughout the world.

Of course, it would be impossible to do the subject justice without discussing the elephant in the room: the June 2016 opening of the expanded Panama Canal, just months before the 102nd anniversary of the original opening of the canal in August 1914. The Panama Canal has had a profound impact on shipping and naval architecture—we have been living in a Panamax world. After nearly a decade and more than $5 billion, "neo-Panamax" is finally here with maximum allowable beam, length, and draft increased significantly. In broad terms, the expansion nearly triples the capacity of containerships transiting the canal. What will neo-panamax mean for naval architects and marine engineers? In these pages, we offer three complementary articles that focus on that question and explore what the relaxation of these constraints may mean for vessel designs, as well as for energy efficiency.

Moving toward greater use

Within the U.S., we continue to see movement toward enhanced use of our inland waterways as part of a system of "marine highways." Some 12,000 miles of inland and intra-coastal waterways are maintained by the U.S. Army Corps of Engineers (USACE), transporting more than 600 million tons of cargo annually. For some commodities, the inland waterways are essential. For example, more than 60% of U.S. grain exports are transported by waterway. Inland waterways offer untapped capacity. One standard dry cargo barge can move the equivalent of 70 truckloads or 16 railcars. Barges are even more efficient for liquid cargo, carrying the equivalent of 144 truckloads or 46 railcars. While many readers may be familiar with the USACE role in maintaining inland waterways infrastructure, fewer may understand the role played by the Maritime Administration (MARAD). I had the opportunity to interview Lauren Brand, MARAD's associate administrator for intermodal systems development for our Policy Briefing section in this issue (see page 16). Brand directs a national port infrastructure modernization program in excess of $1.3 billion and is responsible for the continued development of the marine highway initiative within MARAD. We explored the administration's role in infrastructure modernization for inland waterways, as well as lessons learned related to marine highways.

Marine highways is, in fact, a global initiative, with many countries actively examining ways to more effectively incorporate inland and coastal waterways into their transportation network. Europe has seen success in the use of short sea shipping, where water routes are often shorter and more efficient than land routes. In this issue, Martin Svanberg, Christian Finnsgård, and Viktor Daun make a case for a further modal shift in Europe to greater use of urban waterways for the transportation of goods to, and waste from, urban areas (see page 32).

I hope you find this issue interesting and thought provoking.

Dr. Matthew Tedesco
SNAME (MT) Editorial Board

Coming Soon in *(mt)*

We'll dive into subsea operations in our January issue of *(mt)*, exploring the ways in which ROVs and AUVs enable activities in the ocean's depths; the challenges of cofferdams and underwater ship husbandry; the question of control of the seafloor commons; and a whole lot more. Look for the January *(mt)* as we ring out 2016 and ring in 2017.

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Harsh Shah is a New Jersey-based naval architect/marine engineer currently working as a staff engineer/naval architect at Weeks Marine Inc. His expertise includes ship design, ship structures, hydrostatics, vessel modification, and vessel conversion. He currently holds the office of treasurer of the SNAME New York Metropolitan Section and is actively engaged in coordinating SNAME's young professional activities. Originally from Mumbai, India, Shah graduated from K.J. Somaiya College of Engineering (Mumbai University) with a bachelor's degree in mechanical engineering. After a brief stint at Hafele India, he came to the U.S. to pursue his master's degree in naval architecture and marine engineering at Stevens Institute of Technology in Hoboken, NJ.

EXPA

IMPACT

BY HAAKON-ELIZABETH LINDSTAD

NSION

One of the new post-Panamax designs, MV *Thalatta*, owned by Wilh. Wilhelmsen ASA and operated by Wallenius Wilhelmsen Logistics, has a beam of 36.5 m and a capacity of 8,000 cars.

How the Panama Canal expansion is affecting global ship design and energy efficiency

In 2006, the Panama Canal Authority decided to build new canal locks and widen and deepen the canal in order to enable significantly larger vessels to pass through the canal, which connects the Atlantic and Pacific Oceans. For a small country such as Panama, this was a major investment intended to achieve economies of scale by enabling larger vessels for existing trades to pass through the canal, resulting in reduced transport costs. It also would enable vessels too large for the existing canal to re-route and thus reduce their voyage length and cost, and it would make the sea route from Asia through the canal directly to the East Coast of the U.S. more competitive in terms of the West Coast and the land bridge route across the country to the East Coast.

Apart from a few scientific papers, there has been relatively little focus on how the canal's expansion will influence ship design and thus the energy efficiency of the global merchant shipping fleet. Seagoing vessels traditionally have been designed to operate at their boundary speed based on hydrodynamic considerations. For any given hull form, the boundary speed can be defined as the speed range where the resistance coefficient goes from a nearly constant value to rise rapidly as speed increases. For an average Panamax bulker or tanker with block coefficient in the 0.85 to 0.9 range (1.0 for a shoebox), the boundary speed area starts at 12 to 13 knots, with a gradual increase in the resistance coefficient, which approaches infinity at speeds above 16 to 17 knots.

As a simplification, the form of the resistance coefficient can be compared to a quarter pipe, where the flat area in the bottom represents the lower speeds at which the power required for propulsion is a function of the speed to the power of three. The usual naval architecture practice is to pick the achievable speed in the middle of the quarter-pipe curve, where the power required for propulsion is a function of the speed to the power of four to five (usually known as the maximum economic speed), and to install the required power to achieve that speed. For Panamax bulkers, this typically has resulted in design speeds of 14 to 14.5 knots and maximum speeds of up to 15 knots under calm water conditions. Comparing vessel types, more slender vessels designs such as deep-sea car-carriers and container vessels typically have block coefficients in the 0.55 to 0.65 range. This gives boundary speeds of 20 to 25 knots.

Higher fuel prices and growing environmental concerns have challenged the practice of maximizing cargo-carrying ability and the practice of designing vessels to operate at speeds where the power required is a function of the speed to the power of four to five. For this reason, interest is growing in the relationship between speed and emission reductions. The core insight is straightforward: the power output required for propulsion is a function of the speed to the power of three to five and beyond. This simply implies that when a ship reduces its speed, the fuel consumption per freight work unit is reduced. Increasing vessel size is another means of reducing emissions,

TABLE 1: THE WORLD FLEET

Years built	Beam < 33.3 m	32.3 m – 49 m	Beam > 49 m	Beam > 32.3 m	Beam > 49 m
1970 to 2006	67,491	2,186	935	4.6%	1.3%
2007 to 2016	32,914	3,742	1,288	15.3%	3.4%
On order	3,992	972	490	36.6%	9.0%

Source: Sea web database, July 2016

because larger ships—and cargos—tend to be more energy-efficient per freight unit (per ton-mile of goods transported).

Increasing vessel size is another means of reducing emissions, because larger ships—and cargos—tend to be more energy-efficient per freight unit (per ton-mile of goods transported).

The key observation here is that when cargo-carrying capacity is doubled, the required power and fuel consumption typically increase by about two-thirds, so fuel consumption per freight unit is reduced. The building cost of the vessel increases by about half of the increase in cargo capacity, and crew, maintenance and management costs rise less than in proportion to cargo capacity. While speed reductions and economies of scale often require changes in the supply chain due to longer transport times when the speed is reduced or larger storage facilities when cargo sizes are carried by larger vessels, energy-efficient designs can be introduced without logistical changes. On the other hand, infrastructure limitations regarding maximum allowable measurements tend to limit the opportunities for improving the energy efficiency of vessels that have been designed to pass specific canals and serve specific ports.

The expansion decision

In global terms, of all these restrictions, none had such an impact on vessel design as the original Panama Canal locks dating from 1914, which limited the maximum beam of vessels to 32.3 m. This can be illustrated by the fact that less than 5% of the vessels built before 2007 in today's world fleet have a beam greater than 32.3 m, as shown in Table 1. The new Panama Canal locks, which opened in June 2016, increase the maximum beam to 49 m, the maximum length from 294 m to 366 m, and the draft from 12 m to 15.2 m. As a result of the expansion announcement in 2006 by the Panama Canal Authority, ship owners and ship designers started to develop new wider designs, most of which have been built and delivered to the owners from 2014 onwards. The percentage of vessels with beam above 32.3 m has thus increased to 15% for vessels built from 2007 to the opening of the new locks in June 2016.

Moreover, more than 36% of current orders are for vessels with beam greater than 32.3 m. Some of these vessels—approximately 9% of the order book—are too large to pass even through the upgraded canal, which indicates that the average size of all vessel types in the global fleet is increasing. More specifically, while large crude oil tankers, with dead weights above 250,000 tons, have been built with beams above 50 m since the end of the 1960s, the significant increase in vessel size for the largest dry bulkers and container vessels has taken place during the last decade. In the order book, vessels with beams greater than 49 m account for nearly one third each of containerships, dry bulkers, and tankers, while the rest are construction vessels, drilling vessels, and so forth.

While the economies of scale benefits of expanding the canal are well known and documented, there has been much less focus on how the Panama Canal's expansion could or will influence global ship design and therefore the energy efficiency of shipping. However, there are some studies, one example being "Assessment of Bulk designs Enabled by the Panama Canal Expansion," in SNAME's 2013 *Transactions*, which indicates that the fuel consumption of a typical Panamax dry bulker with a dead weight of 80,000 tons can be reduced by 20% to 25% by increasing the beam from 32.3 m to 38 to 42 m, while keeping the cargo carrying capacity and the length constant, which enables a more slender design and thus reduced power requirements. However, with few exceptions, neither the list of dry bulkers delivered during the past few years in the 80,000-ton segment nor the order book suggest that dry bulker owners are exploiting this opportunity to reduce fuel consumption and cost by building more slender vessels. One reason might be that they are in the tramp shipping market. Unlike a liner ship, which usually has a fixed schedule, the next port of call for a tramp vessel can be anywhere, which means that building a wider vessel will prevent it from serving ports with beam restrictions similar to the original Panama Canal locks.

Containers and car carriers

In contrast, container vessels and car carriers or RoRos are either used in designated liner operations with published schedules or they serve designated ports. This means that all

TABLE 2: PRE- AND POST-PANAMAX CONTAINER AND CAR CARRIERS

Container Vessels	5,000 TEU vessels built for the original Panama canal locks	5,000 TEU vessels built for the original Panama locks	9,000 TEU vessels built for the new Panama locks	13,000 TEU vessels max for the new Panama locks
Dwt	65,000	60,000	110,000	140,000
Length (loa)	294	254	300	366
Beam (meter)	32.3	37.4	48.2	48.2
Draft (meter)	13.5	13.0	14.5	15.5
Installed power (kW)	44,000	24,000	42,000	65,000
Design speed (knots)	24.5	21.0	22.0	25.0
Boundary (knots)	22.7	21.8	22.0	25.0
Capacity in TEUs	5,000	5,000	9,000	13,000
Power per TEU at 20 knots (KW)	5.9	4.4	3.9	3.2
Power reduction		15 - 30%	25 - 40%	35 - 50%

Car Carriers	Car carrier built for the original Panama canal locks	Car carrier built for the new Panama locks
Dwt	21,500	21,500
Length (loa)	200	200
Breadth	32.3	34.8-38.5
Draft	10.0	10.0
Installed power (kW)	16,000	16,000
Design speed (knots)	19.5	20.0
Boundary (knots)	21.5	22.8
Capacity in Cars	6,000-6,500	7,000-8,500
Power per Car at 20 knots (kW)	2.8	2.1
Power reduction		15 - 30%

restrictions are well known and that vessels that exceed specific limitations will be used in other trades instead. The list of new vessels delivered during the past few years and the current order book illustrate that container vessels and car carriers are increasing their beams to enable them to carry more cargo and reduce power consumption per unit as illustrated in Table 2. This table compares three alternative container vessels designs built for the new locks with the typical design built for the original Panama Canal locks, while one alternative car carrier design is compared with the typical car carrier built for the original locks. The values for each of these designs reflect average values for the typical vessels built.

The main observations for the container designs are that keeping the capacity constant, that is, at 5,000 TEU, and increasing the beam by 5.1 m, reduces length by 40 m, reduces the dead-weight tonnage by up to 5,000 tons due to lower ballasting requirements and the energy consumption per TEU by 15% to 30%. Second, if length is kept nearly unchanged, that is, 294 to 300 m, and the vessel is widened to use the new maximum beam, the cargo carrying capacity increases to 9,000 TEU and the energy consumption is reduced by 25 to 40 %. Third, if both length and width limits are fully exploited, the cargo carrying capacity increases to 13,000 TEU and the energy consumption is reduced by 35% to 50% compared to the 5,000 TEU Panamax vessels built for the original locks. Fourth, the

Typical stowage in a RoRo/car carrier operated in a mixed cargo trade.

new designs are now being built to operate at their boundary speeds, while the original Panamax designs were built to operate significantly above their boundary speed.

The new Panama Canal locks, which opened in June 2016, increase the maximum beam to 49 m, the maximum length from 294 m to 366 m, and the draft from 12 m to 15.2 m.

The main observations for the car carriers are that the new designs are wider than the vessels built for the original Panama Canal locks; this increases their car carrying capacity. Second, a new standard beam has not emerged because the new designs have beams of 34.8, 35.5, and 36.5 or 38 m. Third, a larger beam enables an extra car deck to be added, and the greatest increases in capacity have been achieved by the designs that have increased both beam and depth. Fourth, the increased beam reduces ballasting requirements, which means that the cargo-carrying capacity is increased without increasing deadweight tonnage. Fifth, the original designs had design speeds below their boundary speeds and this difference increases further with the latest designs. Sixth, the best combination of parameters needs to be demonstrated through the operators' own experience.

One of these new post-Panamax designs, MV *Thalatta*, which is owned by Wilh. Wilhelmsen ASA (Norway) and operated by Wallenius Wilhelmsen Logistics, has a beam of 36.5 m, which gives two car lanes more than the designs built to pass through the old locks. Moreover, with one additional cargo deck, *Thallata* has a capacity of 8,000 cars in a pure car trades. However, as in any other shipping segment, there are imbalances in trades and it is quite usual for these vessels to be built with stronger main decks combined with movable lightweight decks that can be raised to provide higher main decks when required. Moreover, the car carriers built for these combination trades also have reinforced RoRo ramps that are strong enough even for heavy construction machines and mining machines. One of the images here shows what the stowage might look like when one of these vessels transports such a cargo mix. To avoid potential confusion, the illustration shows the Tønsberg vessel, which is 65 m longer and 5 m lower than *Thalatta*, built with a beam of 32.3 m for the original locks. However, there are not many of these longer vessels, due to berth length restrictions, mainly at Japanese car factories.

More energy-efficient designs

Our purpose here has been to show that the Panama Canal expansion not only contributes to economies of scale, but also to enabling more energy-efficient designs that, until now, have been limited by the beam restriction but not by length or draft. At first glance, it was surprising that only a few dry bulkers have been designed to exploit the opportunity to save fuel and hence operating costs through building more slender hulls.

However, it is certainly no surprise that container and car carrier operators have introduced more energy-efficient designs using the increased beam. What both these vessel segments have in common is that the leading actors, both size-wise and in their willingness and ability to innovate, are based in parts of the world where sustainability and climate change mitigation take high priority.

At present, maritime transport is responsible for 3% of global CO_2 emissions, and maritime emissions are forecast to increase by 150% to 250% until 2050, based on "business as usual" scenarios with a tripling of world trade. In response to these challenges, the Energy Efficiency Design Index (EEDI) and a Ship Energy Efficiency Management Plan (SEEMP) were adopted at the 62nd session of MEPC in 2011. As the EEDI thresholds gradually become stricter, one of the options for meeting the requirements for dry bulk owners (and any other shipping type) will be to build more slender designs that use less fuel and therefore emit less CO_2 per ton nautical mile transported. It is therefore not a big bet to predict that, while containers and car carriers have been the early adopters, dry bulkers and other vessel types will soon follow and start to build wider and more slender vessels. **MT**

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