From Amphora to TEU: Journey of a container

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Abstract

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1. Introduction

In the field of logistics, a container is meant to contain goods (also called ‘commodities’) in order to protect them and to ease their transportation.
Modern containers are large boxes made of metal that can be placed on a truck.
Ancient containers are amphorae, dolia, barrels, sacks.
This presentation aims at comparing ancient and modern chains of logistics rather than giving an exhaustive description of containers and we will therefore concentrate on one type of container for each period of time: the ancient Dressel 1B amphora and the modern TEU container.
After a short presentation of ancient and modern containers, we will try to put ancient and modern logistics side by side on the following aspects:

- Storing on board,
- Loading & unloading,
- Exporting & importing,
- Ships & sailing,
- Return cargo.

Containers should be standardised in order to optimise storage on land and on board transportation means such as ships and lorries. This aim was rather well achieved in modern times with a space-time frame of the whole planet over around 50 years, but was not achieved in ancient times with a space-time frame of the Mediterranean area over around 1000 years.

a. Amphorae

Many different types of amphora have been identified, depending on their date and place of production[1,2]. The first amphorae were used for transport of wine and date from around 350 BC (so-called ‘Greco-Italic‘ type). Many millions have been produced especially during the Roman Empire.

As a volume, one amphora quadrantal is one Roman cubic foot (nearly one modern cubic foot) = 2/3 artaba = 2 modii castrensis = 3 modii = 8 congii = 48 sextarii, or 26 litres. A full amphora (olive oil, wine, fish sauce) weights around 50 kg, out of which around half is tare.

It may be noted that Egyptian grain was transported in sacks of one artaba (39 litres) with a unit weight of around 30 kg.

Note also that wooden oak barrels (500 to 1000 litres) gradually took over from amphorae (and dolia) for storage of wine during the Roman Empire.

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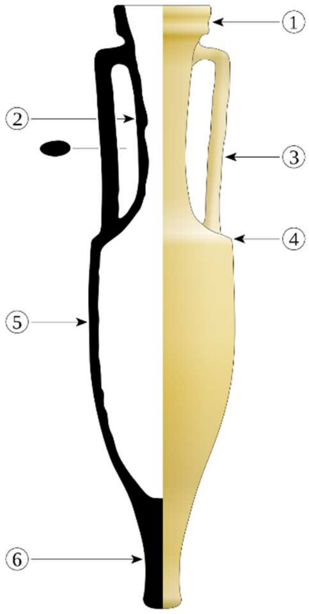
[1] University of Southampton (2014) *Roman Amphorae: a digital resource*
[2] http://www.anticopedie.fr/dossiers/dossiers-gb/amphora.html



Dressel 1B amphora (from https://commons.wikimedia)

<u>Legend</u>:
1- rim (lèvre)
2- neck (col)
3- handle (anse)
4- shoulder (épaule)
5- belly or body (panse)
6- foot (pilon ou pied)

<u>Dimensions</u>:
- Height: 100 to 122 cm
- Diameter of the belly: 28 to 30 cm
- Diameter of the opening: 15 to 18 cm
- Height of the rim: about 6 cm
- Weight: 24 to 26 kg (empty)
- Capacity: 24 to 26 l.

Original manufacture place: Tyrrhenian coast (Etruria, Latium and Campania)

Late Republic period, until 10 BC

b. TEU container

So-called ‘containerization’ was introduced in the 1950’s and the number of containers transported increased exponentially over the past 50 years. It was multiplied by a factor 10 in the last 20 years. Around 500 million container movements are recorded yearly.

The standard intermodal container is designated as twenty feet long (6.1 m) and 8 feet (2.44 m) wide. Additionally, there is a standard container with the same width but a doubled length of forty feet called a 40-foot container which has found wider acceptance, as it can be pulled by semi-trailer truck. Some containers may reach 48 ft and even 53 ft. The height is 8 ft 6 inch (2.59 m).

As a volume, one TEU is around 33 m^3 and the total weight may not exceed 30 tons, including a tare of around 2 tons[3].

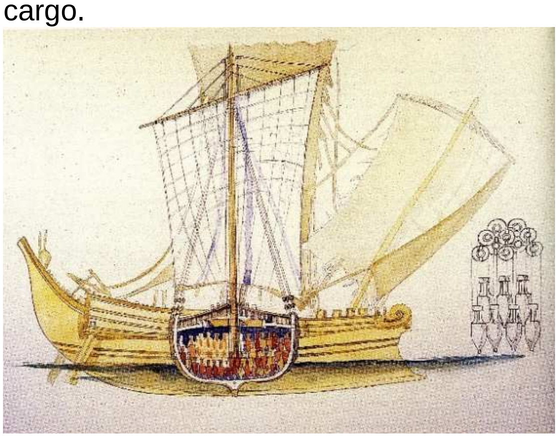
[3] https://www.cma-cgm.fr/produits-services/conteneurs

Twenty-foot equivalent unit (TEU).

2. Storing on board

Ancient

The Madrague de Giens[4] shipwreck discovered in 1967 near Giens in France, had an estimated cargo capacity of 8000 Dressel 1B type amhorae for wine. This is a freight of 400 tons for a 40 x 9 m ship. Thousands of smaller ceramics, or other valuable small cargo, were often placed in-between the amphorae as a secundary cargo.



Arrangement of amphorae on board a ship like the Madrague de Giens (drawing JM. Gassend, 2005).

Modern

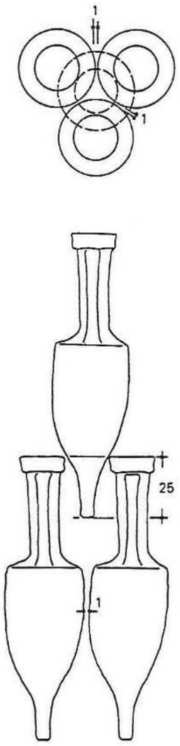
One of the largest container ships is the Marco Polo with a capacity of 16 000 TEU, that is a freight of nearly 200 000 tons for a 396 x 54 m ship[5]. It seems that in 2016 the length is not increasing over 400 m, but the width is heading for 60 m in order to cope with 20 000 TEU on board. This width may become a problem for gantry cranes supposed to load and unload these ships.

The 16 000 TEU Marco Polo container ship (picture CMA-CGM).

A limitation of container ships is their draught of nearly 15 m requiring quay walls of around 20 m height and adequate dredging in order to keep the required water depth.

Containers are stacked on 15 to 20 tiers or levels, half of them in the hold below deck and

[4] https://en.wikipedia.org/wiki/Madrague_de_Giens_(shipwreck)
[5] http://www.cmacgm-marcopolo.com/



Typical arrangement suggested by P. Pomey (1997) based on his work for the Madrague de Giens.

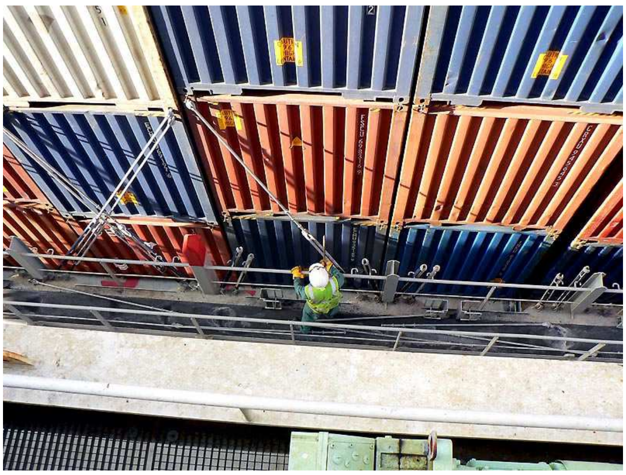
Reproduction of an amphorae arrangement at Antibes' Musée d'Histoire et d'Archéologie (picture A. de Graauw, 2012).

The arrangement shown above with many different types of amphorae is obviously not very optimised.

half on deck. They have to be securely fastened to each other with twist-locks and to the ship's structure with lashing bars.

Twist-lock on a rear corner of a container semi-trailer; the container corner is placed over it and to close the lock, it has to be turned 90°(Wikipedia).

Containers connected to each other by twist-locks (picture F. Massard, 2007).



Checking twist-locks and lashing bars (picture F. Massard, 2007).

Rack and roping device to illustrate how the cargo might have been kept from shifting, at Bodrum Museum of Underwater Archaeology

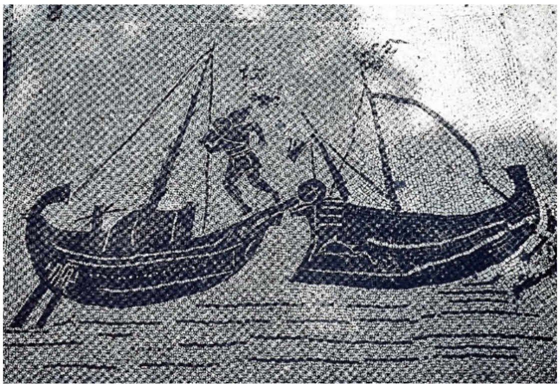
The foot of the amphorae could obviously not be placed directly on the ship's hull as they would perforate it during the trip at sea. Hence, the bottom row of amphorae was placed on some protective layers of straw as shown above. It may also have been sand (perhaps valuable pozzolana?) used both for protecting the hull from the bottom row of amphorae and for ballasting the ship.

Only few accidents happen … (picture http://www.vessels-in-france.net)

3. Loading and unloading

Ancient

One way of unloading a large sea going ship that could not enter rivers was to transfer goods onto smaller ships called lighters (*lenunculus or navis caudicaria*) that were rowed or towed up-river.

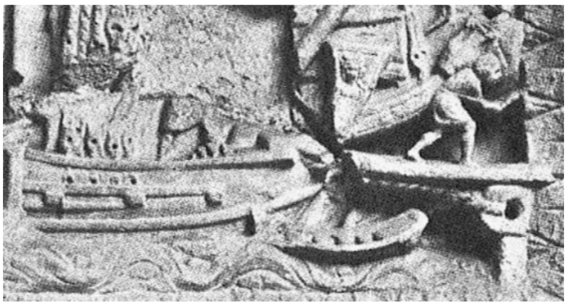


Detail of unloading on a lenunculus at Piazzale delle Corporazioni, Statio 25 (from Pomey, 1997).

Modern

Container ship are loaded and unloaded by means of giant gantry cranes that can reach over the whole width of the ship, i.e. they must lift up to 40 tons at a distance of up to 60 m. This means that modern container ships are always moored alongside the quay.

Five gantry cranes with lifted arm allowing ship movement. In order to save time, even more gantry cranes are sometimes used (picture https://www.marinetraffic.com).



Detail of the Torlonia relief showing a ship moored bow first to a mooring ring with a dock-worker (*saccarius*) carrying one amphora and walking on a gangplank from the ship to the quay. Note the linesmen boat just below the mooring line (picture Testaguzza, 1970, on www.ostia-antica.org).

Early Kerkouros ships usually docked stern first, while later Corbita ships docked bow first as shown on the Torlonia relief above. Alongside docking was required if heavy cargo (live animals, barrels) was to be lifted by cranes or derricks.

Portus Trajanus with nearly 300 berths on 2 km of quay, very few cranes and a vast storage area (*horrea*) (picture Google Earth, 2016).

Fully automated container park at the London Gateway (picture http://www.kalmar.fr).

Ship owners have to optimise the loading of their ship in order to have the boxes ready to be unloaded when reaching each port of call during the trip. They also have to take into account the weight of the boxes and the distribution of loads on board, and many other constraints. This job is not conducted by the captain of the ship any more, but by the company's headquarters using sophisticated computer programmes for this task.

Singapore's container terminals total nearly 60 berths on 17 km of quay, over 200 gantry cranes and large areas for container storage (Wikipedia).

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4. Exporting and importing

International trade is of course a rather complex discipline, but some general aspects can be put forward here in comparison with ancient times.
One constant: fair trade cannot exist without a certain level of trust between the parties, at least at managerial level.

Ancient

International trade was organised by the state for the needs of Rome and of the army (*cura annonae*[6]), but also by individuals from some cities (*civitas libera*) having friendly ties with other cities[7].

Typical actors in maritime trade were:
Negotiator: international businessman involved in wholesale quantities of goods at the gross market (*emporion)*. He could act as a charterer of a ship.
Mercator: local merchant involved at the retail market (*agora)*.
Argentarius: accountant keeping strict books (*tabulae*) which were considered as legal proof by the courts.
Stationarii: soldiers in charge of control and/or gathering of taxes (*ellimenion*).
Mensarius: public banker appointed by the state.
Naufulax, magister navis: captain, master of the ship acting as an employee of the ship owner.
Navicularius; owner of the ship, who entrusted his ship to a *naufulax*. He was a member of his city's professional guild who could negotiate privileges and shipping prices with the emperor's Annona. He could also act as a *negotiator* for his own business.

This relief was found in Portus. Amphorae with wine are being carried from a ship to the quay by dock-workers (*saccarii*). The three civil servants (*tabularii*)

Modern

Contractual documents are meant to specify the object of trade (i.e. the goods), the prices, the conditions of payment, the conditions of termination of the contract in case of unexpected events, and which law shall be applicable in case of a dispute.
Insurances are meant to cover the risk of damage or loss of the goods during their transportation.
Banks use their network to pay the seller in his place of residence with money provided by the buyer in his own place of residence. Banks have no personal opinion on the delivery, they just pay according to the contractual conditions which are taken over into a so-called *Letter of Credit*. This document is put together by intensive use of modern encrypted telecommunications from bank to bank.
A specific document, the *Bill of Lading* (B/L), is prepared by the carrier for the seller upon loading the goods on board his ship; the seller transfers the B/L, and his invoice, to his bank who will send it to the buyer's bank who will pay for the goods so that the buyer can collect the goods from the carrier.
In order to avoid any fraud, *each container is sealed* in presence of the seller after the goods have been loaded. The seals will be broken upon arrival in presence of the buyer.
Several agents may be involved in this process, such as a *charterer* who will look for the right shipping company, *custom agents* who will conduct custom formalities and pay taxes, *shipping agents* will assist the captain with all formalities, etc.

[6] https://en.wikipedia.org/wiki/Cura_Annonae
[7] Arnaud (2015)

take notes. The first porter receives a token of receipt (picture Pavolini, 1986, on www.ostia-antica.org).

Weights, measures and coins were under control of *agoranoms* (in the East) and *aediles* (in the West). *Mensores* and *sacomarii* were legally in charge of measuring and weighting at loading and unloading the ships. *Togati* were in charge of the validation of the trade procedure, including weighing and measuring.

Grain measure at Aula dei Mensores in Ostia. On the left, a porter brings in a sack of grain; the small man is counting the number of sacks, up to 9 to fill the grain measure placed in the centre of the picture; he gives a token to the porter for each sack delivered; the mensor, holding a stick, is in the centre of the picture (from www.ostia-antica.org). According to Arnaud (2015) the man with a *toga* behind the grain measure might be a *togati* and the man on the right the *navicularius*.

It seems that certain cities had a local representative at Ostia (*curator navium*) who would assist the captain (*magister navis*) upon arrival at the port. These agents were long-term residents, part of a trading diaspora, sometimes enjoying double citizenship. They had their own *statio* where traders could meet and get some services, i.a. to find the way in a highly corrupt administration[8], like at a kind of local branch of a Chamber of Commerce of their home-city.

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[8] Arnaud (2015)

5. Ships and Sailing

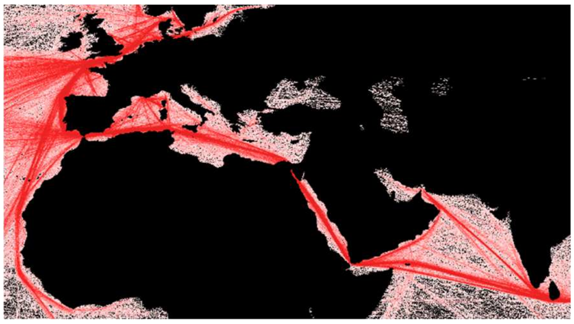
Ancient

Ships were usually associated with a city of origin, like ‘a ship of Alexandria’ in the Acts of the Apostles. It is hard to give numbers, but an estimated 1000-2000 ships were providing food for Rome. Hence, the total number of sizable ships sailing on the Mediterranean, Red Sea and Indian Ocean must have been several thousands.

Main ancient Mediterranean sailing routes

Modern

Ships are officially registered in their ‘flag state’, e.g. 17 % of the world fleet of over 50 000 ships (larger than 500 tons) is registered in Panama or in Liberia (in 2014)[9]. The flag state is supposed to enforce international minimum social standards, safety and environmental, and other international recommendations, on its vessels.



Present-day merchant shipping routes in the Mediterranean Sea and Indian Ocean (Wikipedia).

At first glance, present-day Mediterranean shipping routes seem to be not that different from ancient times! But traffic from China to Europe via the Suez Canal and oil from the Gulf are completely new trades.

In order to understand ancient sailing routes, wind patterns must be analysed, assuming that the meteorological sailing conditions are fairly unchanged over the past few millennia. The prevailing wind direction almost everywhere on the Mediterranean Sea is NW (note that 'prevailing' usually means 'over 50% of time', but not 100%!).

In addition, a *constant* wind direction is required for long-haul offshore sailing. This is typically the case from Sicily to Alexandria in summer time, but other prevailing wind directions may exist locally, e.g. North on the Aegean Sea, North and NE on the Black Sea and East along the coasts of Algeria. Obviously, some finer analysis is needed to find a way back to Rome from Alexandria. This trip is achieved by using sea breezes blowing in the afternoon from the sea to the land[10]. These winds are best felt within a few miles off the coast. They blow more or less perpendicular to the coast, but may locally reach an angle of 45° or even be parallel to the coast. So here is the conclusion:

Going East can be achieved by long-haul offshore sailing, and going West has to be done by coastal cabotage.

The trip to Rome is therefore much longer than the trip to Alexandria as it not only is longer in distance, but it also involves much waiting for favourable wind conditions.

The trip from Alexandria to Rome goes North along the Levantine coast, then West along the Turkish coast to Rhodes, then through the Aegean. The Aegean Sea is famous for its northern wind called Meltemi which makes its East-West crossing a subtle operation using local winds around the islands. The route through the Aegean Sea is still a matter of debate, some favour the northern route, but those not going to Athens prefer the southern route avoiding the dangerous Cape Maleas. West of the Peloponnesus, the Ionian Sea with prevailing NW winds has to be crossed, probably by following the Greek coast before crossing over to Calabria and to the Messina Strait.

[9] http://www.emsa.europa.eu/implementation-tasks/equasis-a-statistics/download/3640/472/23.html

[10] Rod Heikell (2012), Chap 6, pp 312-313:

The Western Mediterranean is subjected to low pressures travelling from West to East and inducing a counter-clockwise wind pattern. Hence, on the French South coast, the wind will blow from South to East first, then turn to North to NW, generating the famous Mistral and Tramontana. This explains that it can be difficult to sail from Marseille to Cabo de Creus and that this has to be done close to the coast to avoid high offshore waves induced by the Tramontana. The trip back may lead through the Baleares and Sardinia, where the westerlies will prevail, then along the western coasts of Sardinia and Corsica where a southern wind may blow. Those going to Rome will take the dangerous Strait of Bonifacio between Sardinia and Corsica.
The coast of North Africa is prone to summer easterlies between Cap Bon and Oran, but has a lack of wind between Oran and Gibraltar … in addition to adverse east-going surface currents of Atlantic water compensating the Mediterranean evaporation.
The Tunisian Golfe de Gabes and Libyan Gulf of Syrt have a tidal range up to 1 m inducing tidal currents that can be used by sailors in both directions. The summer winds may blow from North to East.
The access to the Black Sea is very difficult because of the strong southward surface current of fresh water flowing towards the Mediterranean Sea, in addition to NE winds. Inside the Black Sea, currents flow counter-clockwise and favour a trip to the East along the Turkish coast, before crossing over to Crimea against prevailing winds. Nevertheless, ancient seafarers are known to have sailed massively along the western Black Sea coast to Crimea and to the Azov Sea, possibly because this trip was free of pirates.

The need for a large number of shelters follows from the fact that sailors may need to wait for proper wind conditions or may try to escape bad weather conditions. Even though they can sail 50 to 100 nautical miles in a day, it is important the *kybernator* knows where to find a safe shelter within two to three hours of navigation, i.e. only approx. 10 miles.

It has hopefully been made clear in this (very) brief survey of Mediterranean sailing that it was (still is) a vast and complicated subject that requires a lot of experience.

History shows that Mycenaeans (ca. 1500-1200 BC), Phoenicians (ca 1200-150 BC) and Greeks (ca. 800-300 BC) were very good at sailing. Mycenaean sailors had a very difficult playground in the Aegean Sea. Perhaps their experience was later taken over by Phoenicians who used it to travel all over the Mediterranean Sea and beyond.

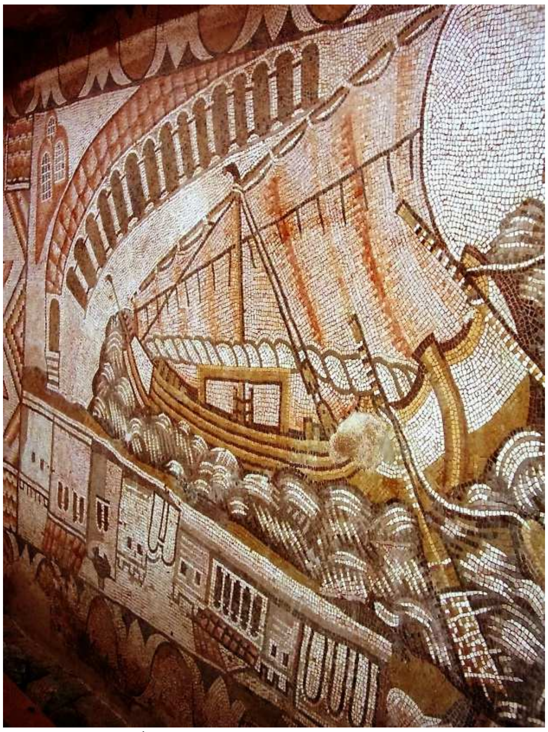
But let’s go back to our ‘Ancient’ and ‘Modern’ comparisons.

Ancient

The picture below shows that a ship with a square sailing rig can sail to windward reaching an angle to the wind direction of around 60°, just like a modern sailing boat would do under spinnaker at beam reach.

Kyrenia II (3rd c. BC) sailing at close reach with a square sail on the Aegean Sea in 1987[11] (picture Pomey, 1997).

This was a must to sail on the Mediterranean Sea and on the Red Sea from East to West, but it surely was (and still is) not a comfortable trip …

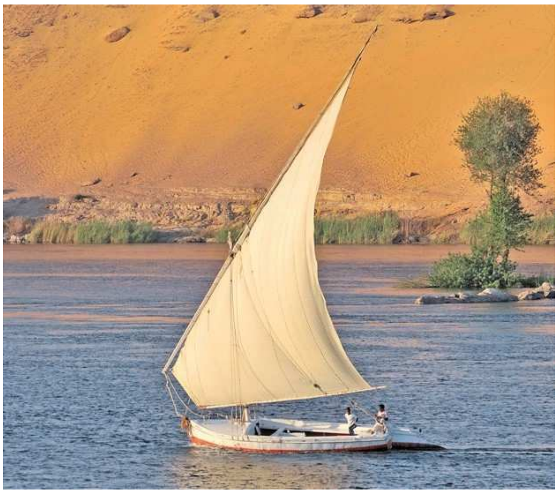


Kelenderis 5th c. AD mosaic discovered by Levent Zoroglu in 1992, showing a ship with partially brailed sail with the top yard pointing down to the bow, making the rig look like a lateen rig (picture Levent Zoroglu).

Modern

Modern sailing boat under spinnaker at beam reach … rather sportive! (picture http://www.hotel-r.net).

The Lateen sail is still used nowadays by amateurs in Europe (picture Albufera Parc Natural).



Modern feluka on the Nile (picture http://www.guidelouxor.com).

Container ships are not sailing ships; they are propelled by engine(s) totalling around 100 000 HP (say 1000 cars!). However, they are 50 m high leading to a windage of nearly 20 000 m^2 and this is now becoming

[11] http://kyrenia-collection.org/styled-4/styled-7/index.html

Note that although the harbour city is depicted, the ship is sailing in rough seas with many waves. In this picture, you can almost feel the rough sailing conditions at close reach with a brailed sail. Such a picture of a sailing ship in full action is very rare as artists never had an opportunity to see this from the shore.

From a sailor's point of view, it was worth trying to reduce the length of sail-cloth susceptible of sagging on the luff side. This sail setting probably led to the triangular shape of the lateen/settee rig pointing into the wind. Furthermore, the lateen sail consisted of less components than the square sail, but it required more crew to be handled[12]. The square rig and the lateen rig obviously had pros and cons and mariners made their own choices. Whitewright (2011) shows that the lateen rigs performed only very slightly better to windward than square sails and *this explains why both coexisted for many centuries*.
Sailors are not conservative at all when it comes to sail settings and they may very well have used the triangular setting of the square sail for many centuries before the Kelenderis mosaic picture.

a limit for manoeuvring them in winds over 35 knots (65 km/h, or wind force 8 Beaufort). As a consequence, modern ships are sometimes told to stay outside of the port in order not to take any risk when entering the port under unfavourable conditions. This is financially unattractive as modern ships are on tight schedules and as 'time is money'.

MOL Comfort (316 m long) broken in two parts during a storm in the Indian Ocean and sunk in June 2013 (picture http://www.meretmarine.com).

Ships still break under the action of the sea. Although the truth never is totally clear, the MOL Comfort was probably broken by wave action due to the combined effect of some structural weaknesses and of some possible excessive load concentrations on board[13].

6. Return cargo

Ancient
The impressive Monte Testaccio dump in Rome contains over 50 million amphorae, mainly Spanish and North African Dressel 20 olive oil amphorae. Perhaps these amphorae were too fatty and the smell of rancid oil would prevent any other use so that they would have to be disposed of. In addition, these foreign amphorae with a different shape may have been of no value to Roman merchants. Surprisingly, wine amphorae have not been dumped in such large numbers and one might think they have been reused.
Other Italian products such as tiles may have been exported too, but the volumes were probably much smaller than the imported volumes of wheat.

Modern
You will probably never see an empty container ship, except on her first sea trials. This is because containers are reused a number of times. This means that they are filled with goods on a trip e.g. from China to Europe, and mostly empty when they travel back to China. The container ship will look fairly similar on both trips, except for her draught.

Note that the problem with oil tankers is even worse as they never have return cargo and simply use sea water for their ballasting tanks.

[12] Whitewright (2011), See also his 2008 PhD thesis at Southampton University.
[13] http://www.meretmarine.com/fr/content/mol-comfort-la-rupture-de-la-poutre-navire-lorigine-de-laccident

There is also a hypothetical export of pozzolana needed for building large submerged structures. Hohlfelder estimates that 20 000 tons of pozzolana might have been imported for the Caesarea Maritima breakwaters. Pozzolana was also found in the Madrague de Giens shipwreck for stabilising amphorae[14]. In any case, ballast of some kind was required as without ballast a sailing boat would capsize immediately!	xxxxxxxxxxxxxxxxxx

7. Conclusion

- Our modern logistics were already in use more than 2000 years ago!
- Modern logistics might provide some useful insight for assessing ancient logistics, e.g. xxxxxxxxxxxxxx
- In ancient times “time is money” was less important than “have a safe trip back home” …

[14] Brandon et al., p 224-225.

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