A Complete Cargo Cycle

An example on voyage performance

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Abstract

The aim of this thesis was to give a perspective on what aspects need to be taken into account when planning and executing a voyage within maritime transport. The purpose is to provide insight on successful voyage performance.

Using a real-life voyage as an example, the thesis lays out a narrative following mostly the tasks that are the responsibility of the Chief Officer. Supported by clarifying illustrations the thesis acts as a portfolio-like example on a specific voyage.

As a result, the thesis may be used as introduction material to officers' work at sea. It will be helpful for starting officers and people who are interested in the maritime industry.

Language: English Key words: maritime, time-charter, shipping, vessel

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Appendix A – Displacement and Stability Calculations

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1 Introduction

The maritime industry is a complex global web of service providers and customers. The basic idea is to transport cargo, be it commodities or people, from a port to another. I often get the question ”what do you actually do onboard?” by people who seem to have little or no knowledge about how the industry works and sometimes I find it hard to give a satisfying answer without over-simplifying the matter. What lies behind a successful voyage performance is a mystery to many, and I hope to answer a few questions in this work.

My work is a description of a real-life voyage between Puhos, Finland, and Hull, England, carrying timber cargo both in hold and on deck. I will go through the procedures of cargo and voyage planning, loading and discharging operations, explain which regulations apply as necessary, what happens between the loading and discharging ports and finally analyse the voyage performance.

1.1 Background

The performing vessel is a Dutch made general cargo vessel under Finnish flag and owned by a Finnish company. During the time of this voyage, 20.-29.07.2020, it was time-chartered to a German company. The vessel was trading mostly in the North Sea and Baltic Sea regions and had performed similar timber cargo voyages before.

I have been employed by the shipping company since August 2017 and worked on several vessels in the fleet as an OS, second officer and chief officer. During the time of this voyage, I had been working as a chief officer in the company for about two years. I had experience of working as a chief officer from similar type of vessels before, but this was my first time onboard this particular vessel.

1.1.1 Ship particulars

In Figure 1 you may find all the ship particulars as provided by the shipowner. All the details are believed to be correct but without guarantee.

Particulars

Name:	[redacted]
Call sign:	[redacted]
IMO Nr:	[redacted]
Flag:	Finland
Home port:	Mariehamn
Built:	1993
Builder:	Bijlsma Shipy. Wartena
Class:	DNVGL 100A5 E /E1 MC E/E1AUT
Ice Class:	E
P&I:	Gard

Measurements

GT:	1681
NT:	957
DWT:	2530
DWCC Summer:	2380
DWCC Winter:	2280

Main dimensions

LOA:	81,70
LPP:	59,98
Breadth:	11,00
Depth mld:	5,67
Draft:	2,80
Deck cargo:	3,00

Cargo hold

Grain:	3552 m³ / 125'424 cuf
Bale:	3552 m³ / 125'424 cuf
Timber Cap:	3400 m³ (seas./unseas.)
Tank Top:	15 tn/m²
Hatch:	1,5 tn/m²

Tank capacity

Ballastwater:	1081 m³
MGO:	136 m³

Propulsion

Main Engine:	Caterpillar 3512 B
ME Output:	1118 kW
Bowthruster:	Yes
Propeller:	FIXED, 4 blades
Speed (ballast):	11 kn
Speed (loaded):	10 kn
Consumption:	4,5 m³ / day

Figure 1. Ship particulars as provided by the shipowner.

1.1.2 Crew

On this voyage there was a crew of six persons onboard, which is the minimum safe manning according to the vessel's manning certificate, including master, chief officer, second officer, chief engineer, AB and OS/cook. Everybody had been working in the company for at least a year during the time of this voyage. Some had previously been working on other ships of similar type in other companies but were new to this particular vessel.

1.1.3 Chartering

The time chartering contract between the charterer and the shipowner had been made in 2018 which meant that the agreement had been going on for almost two years at the time of the voyage. The vessel had been performing similar voyages under the same charterer before.

1.2 Delimitation

This thesis is based on one specific voyage on one specific vessel. The trade area, manning, type and size of the vessel may have impacts on the procedures described in this work and therefore one should not make generalizations based on the details provided. To protect the anonymity and business secrets of the owners and charterers, as well as ship's crew, none of their names will be mentioned in this thesis.

2 The Voyage

The voyage from Puhos to Hull took place between 20.-29. of July 2020. In this chapter I will explain the details of each part of the process from loading to discharging. For convenience, the chapter is divided into sub-chapters according to the topic on hand.

2.1 Planning

The planning of each voyage consists of several different steps. Chief officer is in charge of planning the cargo operations and the second officer takes care of the route planning according to master's instructions. Sufficiency of bunker, provisions and freshwater is among the many responsibilities of the master.

2.1.1 Voyage instructions

Before each trip charterers provide the vessel voyage instructions with the information necessary to perform the voyage. The document states the loading and discharging ports, acting agents in both ports and the amount of cargo to be loaded. There might be other details included, such as procedures in reporting cargo damage or whether the cargo is rain sensitive. In our case it stated that a timber cargo of full capacity was to be shipped from Puhos to Hull.

2.1.2 Cargo planning

Although I had no previous experience of timber cargos, the vessel had been performing similar voyages earlier. This meant that I could use previous information as support material in planning of cargo operations. The voyage instructions did not specify any amount of cargo but referred to full capacity, which means as much as safely possible, bearing in mind any restrictions that could affect the intake. After loading is completed the final amounts will then be inserted into the bill of lading. For my stability calculations I am mainly interested in the weight, but timber cargos are measured in shipped volume. This figure will be provided by the terminal and I will have to determine the weight by the means of draught survey.

Port of Puhos is located in lake Saimaa, where regulations restrict maximum draught to 4,35 meters. This means that we would have 11 centimetres spare distance to our summer draft mark. Other limiting factors are stability and visibility. Stability is usually not an issue with timber cargo since they are not very heavy, meaning that we can keep some of the ballast water in to increase stability. Visibility requirements are defined in SOLAS Chapter V, regulation 22, and state that objects in water two lengths of the ship (or 500 meters, whichever is less) in front of the ship, should be clearly visible from the bridge. On this particular vessel it meant that the deck cargo at even keel could be about 2 meters high from the aft to the centre of ship and about 1 meter high from centre of ship to forecastle.

According to previous experience, the ballast tanks DB 1 SB, DB 1 PS, DB 2 SB, DB 2 PS, DB 3 SB and DB 3 PS (i.e., all bottom tanks) can be left full while the wing tanks (WT 1 SB, WT 1 PS, WT 2 SB, WT 2 PS) and forepeak (FP) should be emptied. The hold would be fully loaded and on deck we could take one full layer and an additional layer from the hatch cover crane to midship. Entering these specifications, and the approximate weights from previous cargoes, into the stability program we can calculate that the draughts would be 4,35 meters in aft and 4,10 meters in forward, and the stability criteria would be met without problems. In reality the final figures will most likely be slightly different since they are affected by how the cargo will be stowed in the hold as well as the weight of the units. These are, however, satisfactory figures for the initial planning and thus we can start the loading operations.

2.2 Loading

In this chapter I will explain the details of the loading procedure, e.g., how to carry out a draught survey and calculating stability before departure. The section is divided into sub-chapters according to phases of the loading operation. The phases are initial draught survey, loading into the hold, intermediate draught survey, loading on deck, final draught survey and stability calculations. Lashing of the deck cargo concludes this section. However, some preparations for lashing must be done together with other phases and they will be explained in the relevant sub-chapter.

We arrived in Puhos a day before the loading was supposed to commence, so I had plenty of time to make a draught survey. While most bulk cargoes are measured by weight, timber cargoes are usually sold per cubic meter. This figure was provided by the agent of loading port and entered into the bill of lading. However, for stability calculations we need the weight of the cargo both in hold and on deck. As there is no such information available, we need to determine the weight ourselves by doing a draught survey.

2.2.1 Initial draught survey

In the initial draught survey, we set a starting point for loading by calculating the initial displacement of the vessel. Later on, the figures of final draught survey will be compared to the initial one's to determine the cargo weight.

All of the figures in the stability booklet are correct for water density of 1,025 tonnes per cubic meter but in reality, the density around the ship in port might be something else, which is called dock water density. We can measure this by putting a hydrometer into a container filled with water surrounding the vessel. The hydrometer will float and has a scale on the side, and the dock water density reading is taken from the point where the scale submerges, as shown in figure 2.

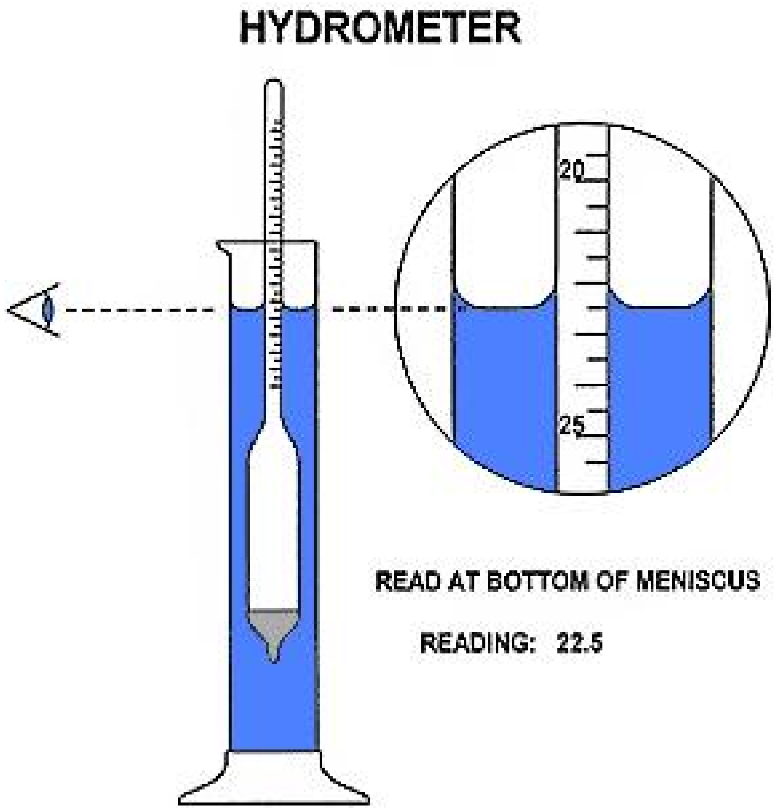


Figure 2. Measuring dock water density with a hydrometer. (Beerlab, 2014).

The draught marks in forward and aft can be read from the quay and the midship draughts have to be calculated. To do this, we measure the distance between sea water level and deck line at the draught mark and subtract that number from the keel to deck line distance, which we can find from, e.g., the stability booklet. In displacement calculations we use the so called mean of means, which is the calculated average draught of the ship. To calculate the mean of means we add six times the mean midship draught with draught in aft and draught in forward and divide the result by eight. You can find detailed information about the calculations in Appendix A.

Ballast tanks which should be full are overflown to make sure that they actually are, and the rest of the tanks will be sounded to determine the volume contained. Sounding is done by applying water finding paste to a sounding measure, lowering the sounding measure to the bottom of the tank through a sounding pipe and lifted back up again. The water sounding paste will change colour when wet, so you can see from the measure where it has become wet. This is where you read the distance on the measure and by comparing the figure to a sounding table you can get the amount of water inside. Each tank has its own sounding table with the water volumes for given sounding level and usually separate tables for trim corrections.

The chief engineer keeps track of the content of other tanks than those for ballast water. Every morning the tank log is filled and brought to the bridge. MGO, sludge, sewage, lube oil and freshwater tank levels can be read from this list, and the information can be transferred into draught survey calculations.

When we know the weights of each tank's content, we can move on to the actual displacement calculation, as shown in Figure 3. First, we take the stability booklet and find the displacement figure that corresponds the mean of means we calculated earlier and apply the relevant trim corrections. From this figure we subtract the deductibles, which include stores and weight of the tank contents, and correct for dock water density. Please refer to Appendix A for an example of displacement and stability calculations with explanations of trim corrections. Finally, we subtract the light ship weight. The remaining figure is the so-called constant which is the difference between the designed light ship weight and the actual displacement. Light ship weight usually increases over time due to e.g., sediments in ballast tanks and, fouling of hull and accumulation of stores, and this is taken into account in the draught survey. (Marine Surveyor Dubai, 2021)

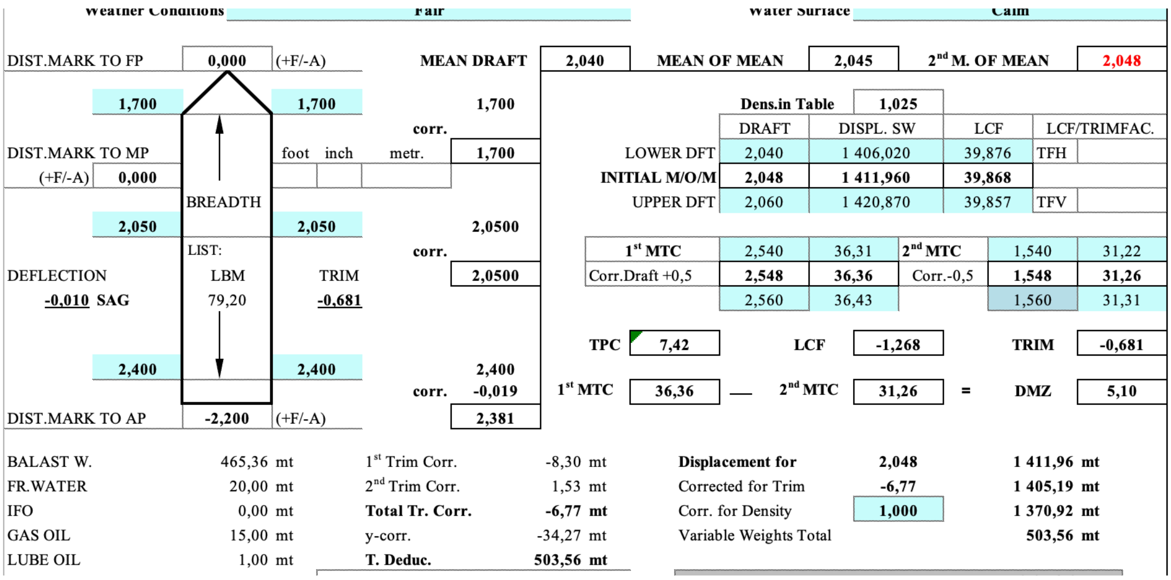


Figure 3. Displacement calculations. (Björk, 2021).

2.2.2 Loading in holds

The vessel is equipped with pontoon type hatch covers, which can be moved with a specifically designed gantry crane. Moving of the hatches should not be done at the same time as reading of the draught marks, since it will affect trim and therefore jeopardise the figures. On this specific vessel, there are eight hatches, which weigh eight tonnes each and can be put into stacks of four. For convenient identification, the hatches are numbered from #1 to #8, the first being the one in the forward and last being the one in the aft. The joints between hatches are inclined and have rubber sealings, one resting on top of the other, to provide water integrity. This means that some hatches need to be opened before others. On this specific vessel the hatches #2, #4 and #6 can be opened first. See Figure 4 for details of hatch joints and example positionings.

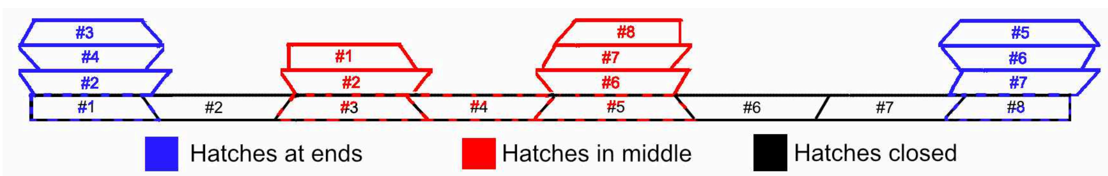


Figure 4. Hatch joint relations and positioning examples. (Björk, 2021).

I had decided together with the stevedoring foreman to start loading operations in the forward, so we move all the hatches in two stacks to positions #6 and #8. The slings, that we prepared earlier into bundles in the hold, will then be lifted out by the crane driver and the stevedores start slinging the timber packs. One pack is fitted with two slings, one in each end, and the crane can lift two packs at once. Stevedores ashore attaches the slings to the crane and the foreman is in the hold guiding the crane driver and doing the unhooking. The foreman's goal is to stow the cargo as well as possible for maximum intake. To accommodate this need, timber packs in Puhos have been prepared in various sizes and the foreman can ask for specific sized packs by radio.

Figure 5. The cargo is loaded in layers of three until the midship section. (Björk, 2020).

The cargo is stowed three layers high until about the middle of the hold as seen in Figure 5. Three layers is about half the height of the cargo hold and we load like this to avoid extreme trim. If we would load all layers in the forward at once, we would end up with such a forward trim that the operation of the gantry crane would be impossible. With three layers the trim is still manageable, and we are able to move the hatches to positions #1 and #3. Next step is to load the aft part of the hold and now we can do it with full layers. With some cargo already in the forward, the trim won't be an issue at this stage. The trickiest part is the final layer because we want as much cargo as possible but can't load over the coamings since we wouldn't be able to close the hatches anymore. For this purpose, some of the timber packs have been prepared in half the height than usual and we can fit an extra half layer. When the aft is fully loaded, we can move the hatches back to positions #6 and #8 and finish loading the forward part of the hold. As they load start with the forward again, I will tell the engineer to execute ballast operations and empty the forepeak tank. As we only had to empty one tank, which takes about thirty minutes, we could do it at this stage.

When the hold is full, we can close the hatches. When all the hatches are in place, I will prepare for the intermediate draught survey as the AB and second officer secures the cleats and wedges and start preparing for loading on deck.

2.2.3 Intermediate draught survey

For stability calculations we need the weight of the cargo loaded in the hold. To determine this, we need to do an intermediate draught survey and compare the figures to the initial draught survey. When all corrections and deductions are done properly, we will end up with a change in displacement which is equal to the amount of cargo onboard.

The intermediate draught survey is conducted exactly as the first one, although some of the information will stay the same. During such a short port call with a small ship, there is practically no consumption on fresh water or bunker at least to an extent that it would affect our stability. The only deductible in this case that had changed was that the forepeak ballast tank, which was now empty. Therefore, the calculations themselves we're simple. We take the new draught readings, calculate mean of means, find the corresponding displacement figure from the stability booklet, correct for trim, subtract the deductibles and lightship and we get a figure that matches the amount of cargo onboard. Figure 7 shows the final draught survey report which include all the stages as described above and the total amount of cargo on board. In holds we have 1421 metric tonnes.

When we know how much cargo is in the hold, we can make a quick check of how much we are able to load on deck. In our stability program I can enter the weight, LCG and VCG of the cargo and it will automatically do the calculations for change in stability. First, I enter the details for the cargo in hold, and then I separately enter the details of the deck cargo. Based on previous experience I knew that one layer of timber on deck is approximately 200 metric tonnes and that we could accommodate about one and a half layers, resulting in a total of 300 metric tonnes deck cargo. By entering these values into the program, it shows draughts of 4,06 meters in forward, 4,28 meters in aft and a GM of 0,62 meters. For the details of stability calculations, please refer to Appendix A, but these figures now meant that we are fulfilling every criterion and can proceed loading on deck.

2.2.4 Loading on deck

While I have been doing the survey, the AB and second officer has closed the hatches and fastened the cleats. The deck cargo needs to be covered with tarpaulins and I've found that the easiest way to do that is to have the tarpaulins partly under the deck cargo and lift them over when finished loading. This will be explained in detail in chapter 2.2.6. among the rest of the lashing. Before commencing loading on deck, we open the tarpaulins and spread them along the ship's side. Approximately 1 meter of the tarpaulin stays on top of the hatches and the rest is hanging on the side walkways as seen in Figure 6. Additionally some wooden dunnage is laid on the hatches to provide better friction. The reason for this will be discussed later in the analysis section of this thesis.

Figure 6. Tarpaulins were placed under the cargo and folded over after completion. (Björk, 2020).

The loading sequences of the deck cargo was to finish one layer from forward to aft and then load the second layer from aft to midships, as far as possible without jeopardising the visibility from bridge. The hatches are 8,92 meters wide and the timber packs about 1,10 meters wide. This means we put eight rows across the hatches in the first layer all the way to the gantry crane in the aft, which usually is secured at the lifting points on hatch #8.

However, we concluded that we could take an extra row if we secured the gantry crane as far aft as possible and so we did, enabling us with around 45 cubic meters additional cargo.

For the second layer we only lay seven rows across. According to the Code of Safe Practice for Ships Carrying Timber Deck Cargoes (IMO, 2011) this provides a better angle for lashing and gives the stow a binding effect. This is best visualised in Figure 8, which shows the cross section of the deck cargo lashing. The number of rows we can load in longitudinal direction depends, in this case, on the visibility from the bridge. Therefore, we loaded one row at a time and checked the visibility before loading the next. When the second layer was loaded to about midships, we concluded that another row would be too much and made note that the loading operations had finished.

2.2.5 Final draught survey and stability calculations

Next in line after completion of loading is the final draught survey. We do this to determine the weight of the cargo on deck, and in chapter 2.2.3. we estimated the weight to be 300 metric tonnes so we can expect something in that area. None of the tank levels have changed so we can use the same figures as in the intermediate survey. The calculations can be done basically in two ways. Either you can compare the results from the final survey to the intermediate and the displacement difference will tell you the weight of the deck cargo. The other method is to compare the final survey to the initial one and the difference in displacement will tell you the total cargo onboard, from which you have to subtract the weight in hold to get the weight on deck. What I like to do is to calculate with both methods and compare the results as a way of doublechecking for errors.

As you can see from the final draught survey report in Figure 7, the total amount of cargo was found to be 1716,6 metric tonnes. If we subtract the 1421 metric tons of cargo in the holds, we remain with 295,6 metric tonnes on deck.

In the stability program I can enter these weights with their vertical and longitudinal centres of gravities, i.e., their placement on the ship, and the program will automatically calculate the stability conditions. Calculating this manually is not too complicated but takes time and there is always a risk for human error. I have provided a detailed explanation of the stability calculation process in Appendix A. The stability criteria were met, and the GM calculated to be 0,55 meters.

ort:	Puhos, FI		
argo:	Sawn Timber		
ate/ Time :	20.7.2020 22:30	20.7.2020 7:00	20.7.2020 22:30
		Initial Survey	**Final Survey**
raught:			
	forward mean (corrected)	1,700 m	4,170 m
	aft mean (corrected)	2,381 m	4,258 m
	forward and aft mean	2,040 m	4,214 m
	midship's stb	2,050 m	4,160 m
	midship's port	2,050 m	4,180 m
	midship's mean (corrected)	2,050 m	4,170 m
	mean of means	2,045 m	4,192 m
	MEAN / MEAN of MEAN	**2,048 m**	**4,181 m**
	Deflection	SAG -0,010 m	HOG 0,044 m
	Trim	-0,681 m	-0,088 m
EADWEIGHT / DISPLACEMENT (SW)		1 411,96 mt	3 105,00 mt
st Trim Correction		-8,30 mt	2,11 mt
nd Trim Correction		1,53 mt	0,02 mt
EADW./ DISPLACEMENT corr. for trim		1 405,19 mt	3 107,14 mt
orrection for density y =	1,000 / 1,000	-34,27 mt	-75,79 mt
EADW. / DISPLACEMENT corr. for dens.		1 370,92 mt	3 031,35 mt
ariable Weights:			
	Ballast Water	465,36 mt	409,19 mt
	Fresh Water	20,00 mt	20,00 mt
	Heavy Oil / IFO	0,00 mt	0,00 mt
	Diesel / Gas Oil	15,00 mt	15,00 mt
	Lube Oil	1,00 mt	1,00 mt
	Sludge	0,20 mt	0,20 mt
	Other`s	2,00 mt	2,00 mt
ariable Weights Total		503,56 mt	447,39 mt
etto DEADWEIGHT / DISPLACEMENT		**867,36 mt**	**2 583,96 mt**
eight of Cargo:		**1 716,6 mt**	

Figure 7. Final draught survey report. (Björk, 2020).

2.2.6 Lashing of the deck cargo

In the hold it is usually possible to stow the cargo in a manner that no lashing is needed. The packages are well compressed against each other and the sides of the hold and the possible moving would be so minimal that it would not make any difference in neither the stability of the ship or the condition of the packages. However, that is definitely not the case with deck cargo, and it needs to be properly secured and protected from the elements.

For convenience the tarpaulins were already prepared before loading the deck cargo. They were laid out on the edges of the hatches, along both sides and in the forward, in an overlapping manner. This saves time since one side of the tarpaulins will be secured between the hatch and the cargo, and no additional securing is needed for that side. The next step is to lift all the tarpaulins over the cargo and secure the loose sides to the ship with ropes. Ideally the tarpaulins will lay over the cargo as tight as possible so that it will not trap any wind inside, ultimately causing slack to the lashing belts.

The lashing belts are put into place and tightened after the tarpaulins have been properly secured. They are ratchet belts with a WLL of 10 metric tonnes, or approximately 98 kilonewtons. The belts are placed so that each stack is secured by three belts all along the deck cargo. Additional belts were put over the section with two layers as a safety measure.

Hook end of the belt was secured to a D-ring securing point on port side with a shackle and the ratchet's hook was then correspondingly secured on the starboard side. Loose end of the lashing belt was threaded through the gap in the ratchet and the lashings were tightened. The lashing arrangement is shown in Figure 8. Web lashing belts of this type are more prone to introduce slack than, e.g., chain lashings, and the tension needs to be confirmed on a daily basis during the voyage. Having all the ratchets on one side makes this easier.

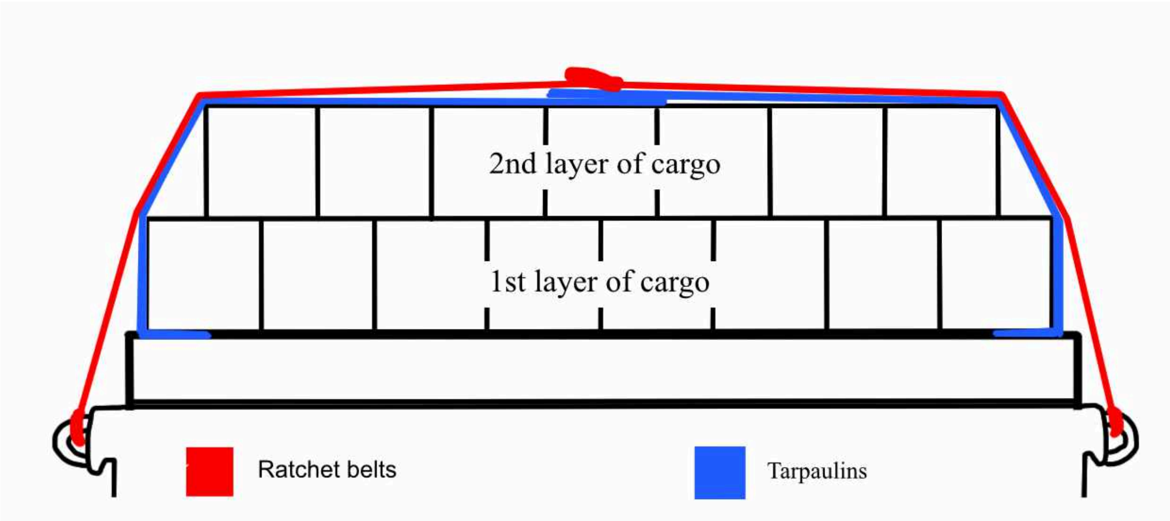


Figure 8. Cross section of the deck cargo and lashings. (Björk, 2021).

2.3 Underway

Before departure the vessel needs to made ready for sea. The lashing of the cargo is done, and the deckhands check that all entrances to hold and other watertight hatches are properly closed. Any loose equipment lying around is stored in their right place. After the pilot is onboard, the gangway net is removed, and the gangway is secured at its designated storage position behind the gantry crane.

Meanwhile the master prepares the bridge equipment for departure. There is a supporting check list that needs to be available on the bridge. This checklist is ship specific but should include, for example, testing of steering equipment, gearbox, bow thruster, navigational lights, radars and ECDIS and checking of passage plan and stability. An example of a departure checklist, as provided in the Bridge Procedures Guide, can be found in Appendix B. (International Chamber of Shipping, 2016)

2.3.1 Departure

When all is set ready for departure the crew takes their assigned positions either in the aft or on the forecastle. To avoid unintentionally drifting away from the berth when unmooring, the master sets the engine control lever to dead slow ahead position and the rudder angle slightly to port. This will push the ship against the quay as we have starboard side alongside. Now it is safe to unmoor all lines but the forward spring line. When the master now sets the rudder amidships, the aft will slowly start moving away from the quay. The master uses the bow thruster to push the forward away from the berth to avoid any possible obstructions and to keep the ship parallel to the quay. When the master is satisfied with the position of the ship, we cast off the forward spring line and are under way. The vessel left Puhos on Tuesday 21.07.2020 05:10 ship time.

2.3.2 Lake Saimaa and Saimaa Canal

Most vessels navigating the lake Saimaa and Saimaa canal require a pilot and our ship is no exception. The pilotage on lake Saimaa is divided into segments of around four hours, which means that there are several pilot changes occurring at pre-assigned positions. On our trip from Puhos to Mälkiä locks, first lock of the Saimaa canal southbound, we had pilot changes at Savonlinna and Puumala before taking the canal pilot inside the locks. I've used material provided in the Traficom regulation for pilotage fairways and pilot boarding positions and compiled it in Figure 9 as an illustration of the journey through lake Saimaa. (Traficom, 2018)

The pilot takes care of the navigation and radio traffic while OOW is supporting them in every way. We are not using additional lookouts on the lake, if not necessary due to circumstances. The pilot may request for additional lookouts if needed or, in case of e.g. dense fog, even order the vessel to drop anchor. In some areas, such as the fairway leading to Puhos, night-time navigation requires two pilots onboard. This was, however, not required in our case since we left the port in daylight.

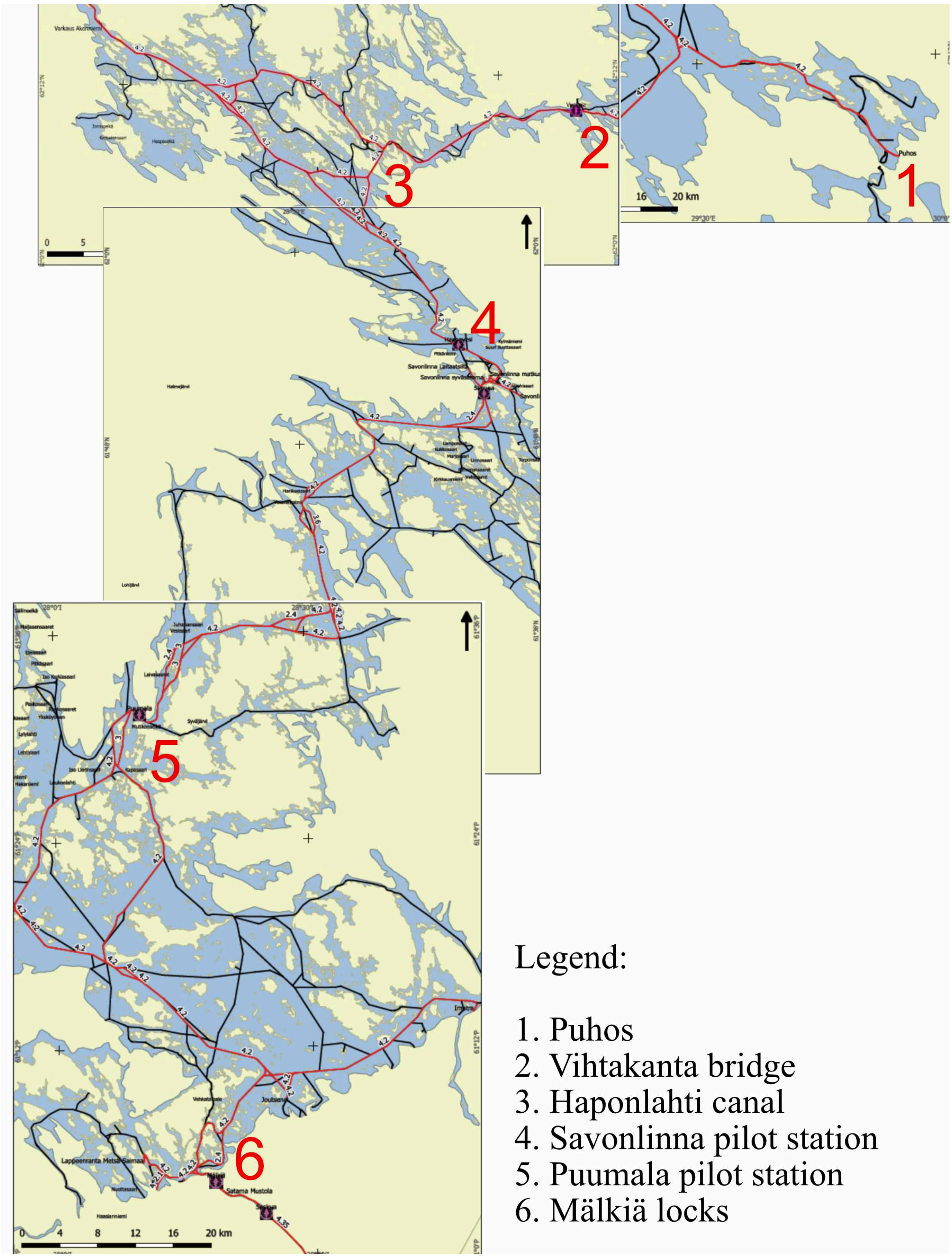


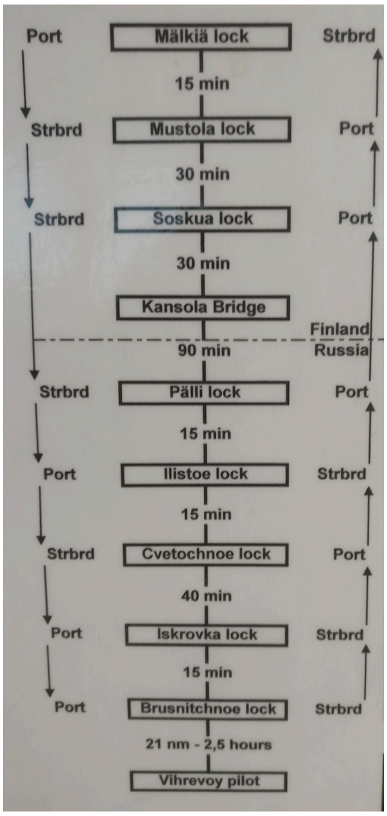
Figure 9. Passage through Lake Saimaa. (Björk & Väylävirasto, 2021).

There are various points on the lake where the vessel needs to report 10 minutes prior arrival to Saimaa VTS on VHF channel 09. The pilot will make the reports, but it is ideal that the master and officers are also aware of the reporting points. One exceptional report is the Vihtakanta bridge, which has to be opened for passage. The opening has to be requested from Saimaa VTS one hour before arriving at the bridge. Our vessel passed Vihtakanta at 06:00 ship time according to the logbook.

The next interesting leg is where we need to take down our masts at the Haponlahti canal. The overhead clearance is only 13,60 meters under the bridge and our air draught in present conditions was 18,90 meters. By taking the masts down we could reduce this to 9,50 meters enabling us to pass through. Both masts need to be operated separately but the procedure is very simple and the same for both masts. In the forward there is one mast wire attached to the deck and in the aft there are two wires attached to the standard bridge that needs to be unfastened. After this you can lower the mast with the same hydraulic system that the winches use. After passing through the canal at 08:05 ship time, we raise the masts and secure the wires again.

The first pilot change just before Savonlinna takes place at 10:10. Based on my experience, pilots on lake Saimaa prefer to embark from the starboard side and that was the case this time as well. The AB is standing by at the pilot gate when the pilot boat comes alongside. Our freeboard is about 1,40 meters so there is no need for the pilot ladders to be rigged. When the relieving pilot comes to out, the AB will open the pilot gate and lead the way to the bridge where the pilots will have their handover. The AB will escort the relieved pilot back to the pilot gate and close it after the pilot boat has cleared off. Before arriving to the Mälkiä locks, we have one more pilot change at Puumala. The procedure is exactly the same as described before.

Saimaa canal consists of eight locks that are placed along the 43-kilometre-long canal, of which around half is located on Russian land. The land is leased by Finland and the pilotage in the area is also arranged by Finnpilot. Maximum dimensions for a vessel entering the Saimaa canal are 82,50 meters in length, 12,60 meters in width and 4,35 meters in draught. The locks are technically and dimensionally identical with the exception of floating bollards. In some locks the floating bollards are placed on the east side of the lock chamber and in



some locks, they are on the west side. This is important to keep in mind since the vessel should moor on the side with the floating bollards. Onboard we have an illustration (Figure 10) of the canal with the bollards identified for convenience. (Väylävirasto, 2021)

Figure 10. Illustration of the Saimaa Canal bollard positions. (Björk, 2020).

The roles of the team members in Saimaa Canal are clear. Master does the entering and leaving the locks, pilot navigates in waters between the locks, AB takes care of mooring in the locks and one of the officers is in the forward acting as guiding eyes for the master when entering and leaving the locks. We have special made mooring ropes that we use only in Saimaa Canal. There is an eye on the other end while the other end is cut to a specific length. When we use the midship bollard and the second floating bollard of the three ones in each lock, the spring line will be exactly of the right length. This makes the mooring easier as you can keep the mooring line on the ship's bollard all the time and just throw the eye on to the floating bollard as the master slowly approaches the side of the lock.

After the ship is inside, the lock chamber closes and water is drained out, lowering the water level in the lock. When the level has reached the same as on the other side of the lock the chamber opens, and the journey may continue. The master eases the throttle so that the AB can easier get the mooring line off the bollard and the officer keeps the master informed about distances to surrounding objects.

There are seven more similar locks with (including Mälkiä) an average total drop of 75,7 meters, depending on the height of the sea level. When moored in Brusnichnoe lock, which is the last lock of the canal, the pilots change before going down to sea level.

2.3.3 Russian territorial waters and Gulf of Finland

From Brusnichnoe lock, via Vyborg and Vysotsk out to sea, the pilotage is rendered by the Russian state owned Rosmorport. The pilot boards in the lock before going down and leaves at the Vihrevoy pilot boarding station outside Vysotsk. The route can be seen in Figure 11. From past experience I've noticed that some pilots want to do the navigating themselves while others prefer to focus on radio traffic and giving orders to the OOW. There are two tighter turns where the pilots usually want to use a helmsman, which will either be carried out by the OOW or an AB will be called up to the bridge. The pilot stands on the bridge wings for better visual references and gives out rudder commands for the helmsman to perform. To avoid misunderstandings, the helmsman will repeat these commands back before carrying them out and the pilot will confirm that the message was understood right. This is called closed-loop communication and is widely used in seafaring where misunderstanding orders could lead to accidents. The pilot disembarks at Vihrevoy pilot station and we proceed following the fairway outbound to sea. When passing buoy Khalli, we make a report to St. Petersburg Traffic with our VHF radio and let them know that we are entering their monitoring area.

Figure 11. Route from Brusnichnoe locks to Vihrevoy pilot station. (Rosmorport, 2020).

St. Petersburg Traffic is part of the Gulf of Finland Reporting System (from here on GOFREP) which is a mandatory ship reporting system that is jointly organized by Estonia, Finland and Russia. Estonia's area of responsibility is Tallinn Traffic, and the equivalent of Finland is Helsinki Traffic. Each country is responsible for the reporting system in the area adjacent to their national waters. These areas can be seen in Figure 12. Between Helsinki Traffic and Tallinn Traffic is the central reporting line which acts as a boundary between the areas. The TSS in the Gulf of Finland runs on both sides with eastbound traffic on Tallinn Traffic side and the westbound on Helsinki Traffic side. There is also a western reporting line that marks the entrance to the GOFREP system to vessels arriving from west.

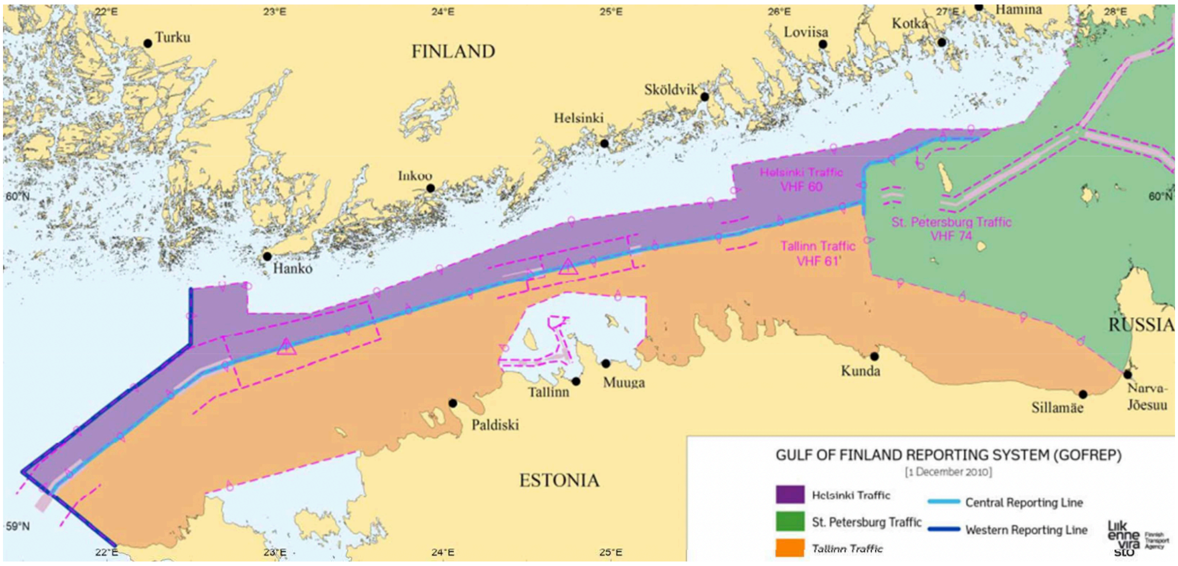


Figure 12. GOFREP areas. (Finnish Transport Agency, 2021).

GOFREP traffic centers monitor the ships by radar and AIS information and provide weather and traffic information as well as navigational warnings. In wintertime they will provide information about ice condition, might recommend a route to be taken and give the contact details of the acting icebreaker.

The traffic separation scheme (TSS) is effective in Russian waters and there are usually no problems even in heavier traffic. Sometimes there might be a pleasure craft without AIS crossing the TSS. In these cases, the VTS is very helpful in letting you know that they have an unidentified object on their radar looking to cross the TSS and you may take actions if required. As we continue, we will pass Buoy #4 which is also a reporting point, and which is in the middle of a roundabout where you have to pay attention for vessels approaching from the east. However, as we are on their starboard side, they are the give-way vessels, and we are the stand-on vessel according to the International Regulations for Preventing

Collisions at Sea, or COLREGs (IMO, 1972). To simplify, this means that they have to stay clear of us and we need to maintain our speed and course. You can see the illustration of the St. Petersburg Traffic area in Figure 13. After the roundabout there are two more reports to make. One at Buoy #1 south of Gogland island and finally when leaving the area. When leaving St. Petersburg Traffic area, you also make a report to Helsinki Traffic and let them know you are entering their monitoring area. They will usually ask the number of persons onboard and whether or not you are carrying any dangerous cargo.

Figure 13. St. Petersburg Traffic area with reporting points and our route. (Björk & OpenSeaMaps, 2021).

The time inside the Helsinki Traffic area is fairly short as we immediately change our course southwest towards Tallinn. We call Tallinn Traffic and let them know that we are crossing the central reporting line and repeat the number of persons onboard and that we are not carrying any dangerous cargo. We will also let them know that we are planning to anchor at Tallinn Roads for bunkering. When proceeding towards Tallinn it is important to keep an eye on eastbound vessels crossing our course since we are then the give-way vessel.

2.3.4 Bunkering at Tallinn Roads

As per our time charter agreement, bunker costs are the charterer's responsibility. It is in their interest to seek a decent quality fuel for a fair price and arrange the transport, and most of the time we take bunker from trucks ashore. One option would have been to take bunker in Puhos, but this was too expensive for the charterer. Another option would have been to take bunker in Kiel Canal, but the master and chief engineer concluded that this would be too much of a risk since the bunker would perhaps not be sufficient for the trip there if, for example, any unexpected heavy weather was encountered.

The price, quality and convenience were met in the decision to drop anchor at Tallinn Roads and take bunker from a barge. The anchorage is inside the Tallinn VTS area, so we needed to make a report when entering and before dropping anchor. The bunker barge had contacted us earlier with the information that they would be at the outer anchorage "India", as pictured in Figure 14, around midnight between 22nd and 23rd of July which suited our schedule well.

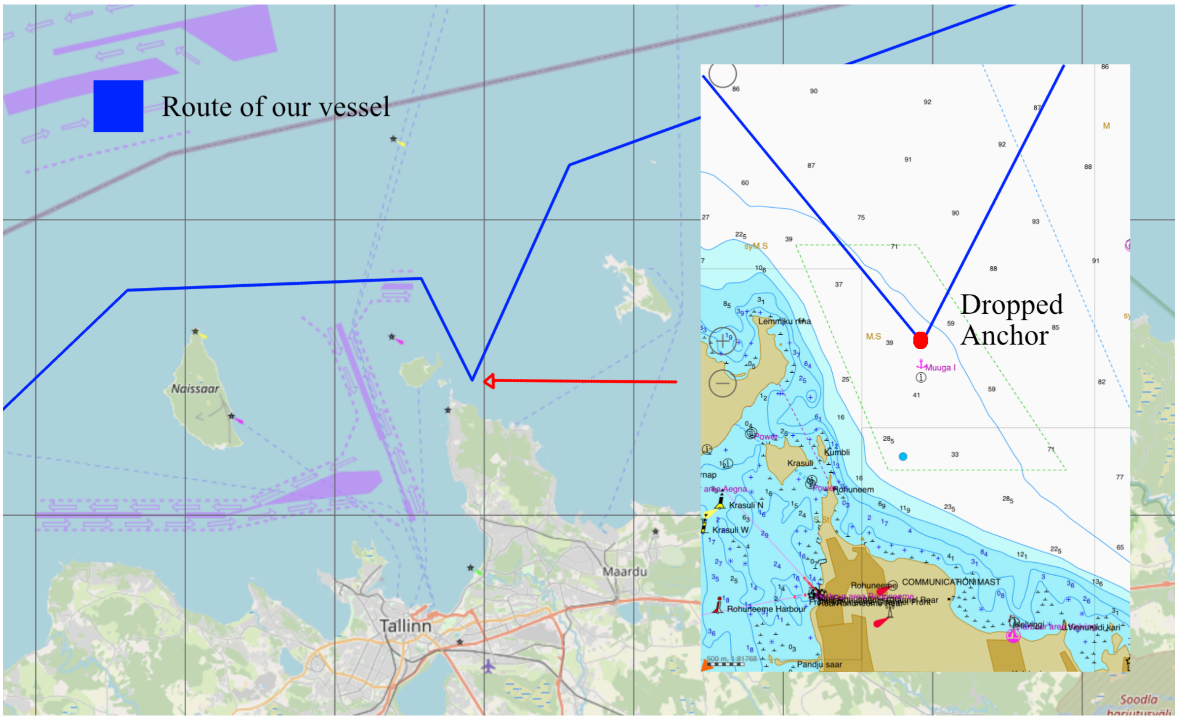


Figure 14. Outer anchorage "India" and the route of our vessel. (Björk & OpenSeaMaps, 2021).

Upon arrival to the designated anchoring area, master steered the ship's bow against the wind and the second officer prepared the starboard anchor together with the AB. The anchor uses the mooring winch but there is a switch that needs to be turned when you want to drop or heave up the anchor. After this switch is engaged you can open the stoppers and breaks and lower the anchor by using the control levers of the mooring winch. First, we lower the anchor to the waterline and then continue lowering upon master's orders. The master ordered us to walk down the anchor leaving the third shackle at the waterline. After this we secured the anchor stoppers, re-engaged the brake and hoisted a black ball shaped day signal halfway up the foremast to let other vessels know that we are at anchor. The master lit the anchor lights which are all-around, meaning they are visible from every direction, white lights at the top of each mast.

The bunker barge was already approaching, and the AB helped them moor to our side. After chief engineer was finished shutting down the engines, he started to prepare the bunker station. On this particular ship the bunker station is on port side. The pipes leading to the bunker tanks are located here in a metal enclosure that acts as an overflow space. That means if the bunker connection for some reason starts leaking, the diesel oil won't spill on deck but gather inside the enclosure where it can be pumped out from later on. The bunker barge gives us the hose which is then connected to the bunker station. By turning a valve, the chief engineer can control to which tank he wants the diesel oil to flow. We have two storage tanks and usually the bunker is distributed evenly between them.

Before we start taking the bunker onboard, we hoist the Bravo signal flag. As defined by International Code of Signals, this means "I am taking in, or discharging, or carrying dangerous goods" and is used to signal others that we are taking in bunker (IMO, 2020). During the bunkering process somebody has to stand by the bunker station at all times. The barge will provide the vessel with an emergency stop button which you can use to immediately cease the bunker flow in case of leakage. After the bunkering process is completed and the barge has left, the chief engineer will start the engines and the vessel is ready to lift anchor.

Heaving up the anchor is done in opposite order compared to lowering it. In addition, we will open up the valves for anchor chain wash and start the fire pump. This will spray a jet of water inside the anchor hawse pipe and clean the anchor chain as we heave it up, preventing mud accumulation on deck and in the chain locker. When the master is ready, he will order to start heaving and the crew on the forecastle will turn on the pump, loosen the brake and stoppers and start heaving up the anchor. The AB is operating the winch and an officer informs the master in which direction the chain is pointing. From this information the master can decide whether to steer the ship or give a small kick with the engine to help the process. When the anchor is at the water level, we wait for a little while and let the sea wash the mud away, and finally lift it up all the way. The anchor is again secured by brake and chain stoppers and everything is made ready for sea. The vessel was back under way on 23.07. at 02:50 ship time.

2.3.5 Baltic Sea

From Tallinn we continued our trip to the west along the coastline of Estonia. The route, as roughly shown in Figure 15, leaves the Tallinn Traffic area the whole GOFREP system after Hiiumaa island and goes straight over the Baltic Sea to the coast of Gotland. There are no VTS services until Kadetrenden between Germany and Denmark, so the only mandatory radio watch is maintained on VHF channel 16. A lot of bigger ships are crossing the Baltic Sea in the north-south directions and that's something to bear in mind when crossing in the northeast-southwest directions. Situational awareness plays an important role in avoiding collisions and close-quarter situations as the approaching angles might be small. If sharp lookout is kept, it should not be a problem to give way in such open waters.

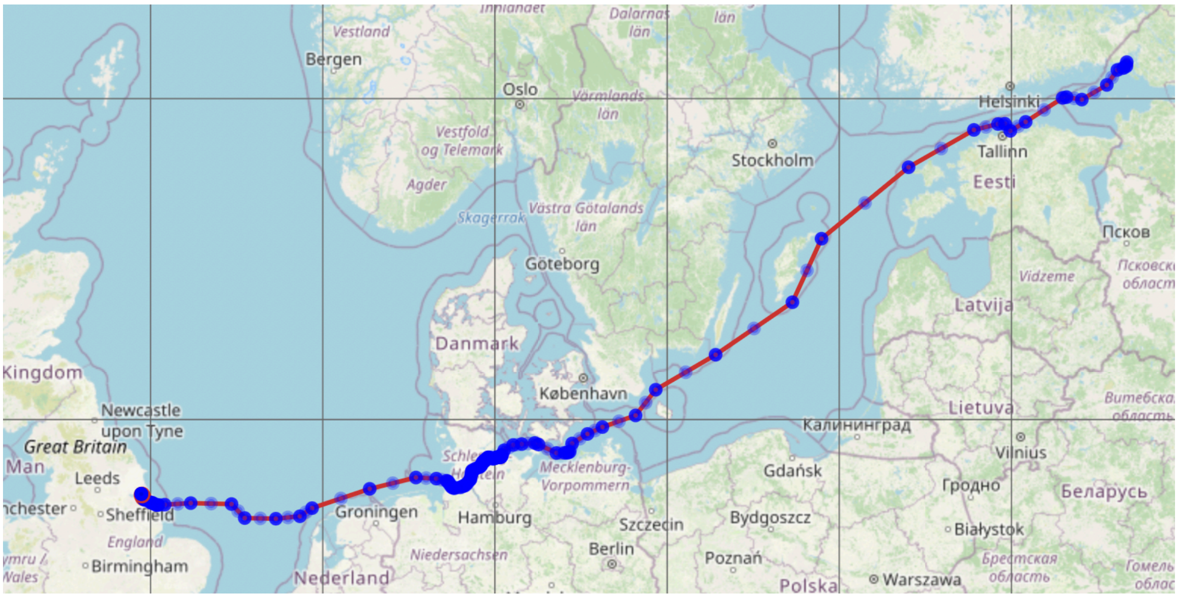


Figure 15. Rough reconstruction of the route from Brusnichnoe lock to Hull. (Björk & OpenSeaMaps, 2021).

Past the southern tips of Gotland and Öland islands, the route continues north of Bornholm and further into the so called Kadetrenden. The traffic separation schemes Bornholmsgat and Kadetrenden are densely trafficked areas compared to the open waters of the Baltic Sea. In Bornholmsgat you have ships entering the TSS from the Sound in west and other ships mainly northbound or southbound. Extra attention needs to be paid to the high-speed crafts between Bornholm and Sweden, as well as the increased possibility of fishing vessels. We are passing Bornholms Norra Grund at 02:00 ship time on 25th of July, according to the logbook.

Kadetrenden is one of the busiest sea routes in Europe with more than 50 000 ships passing by every year, according to an article from 2015 in the German newspaper Täglicher Hafenbericht (Täglicher Hafenbericht, 2015), including a lot of traffic to and from Rostock. Some fishing vessels and smaller crafts may also be crossing the TSS which may cause reason to give way. After passing Kadetrenden the route continues northwest towards Fehmarn Belt, which is also located between Germany and Denmark. You can see an overview of the Kadetrenden and Fehmarn Belt areas in Figure 16. There are several ferries crossing this area between Rödby and Puttgarten, which may affect the navigation. However, it is not uncommon for the ferries to contact you by radio and inform that they will pass our aft and we need not to make any alteration to our speed or course even though we would, according to the COLREG, be required to give way.

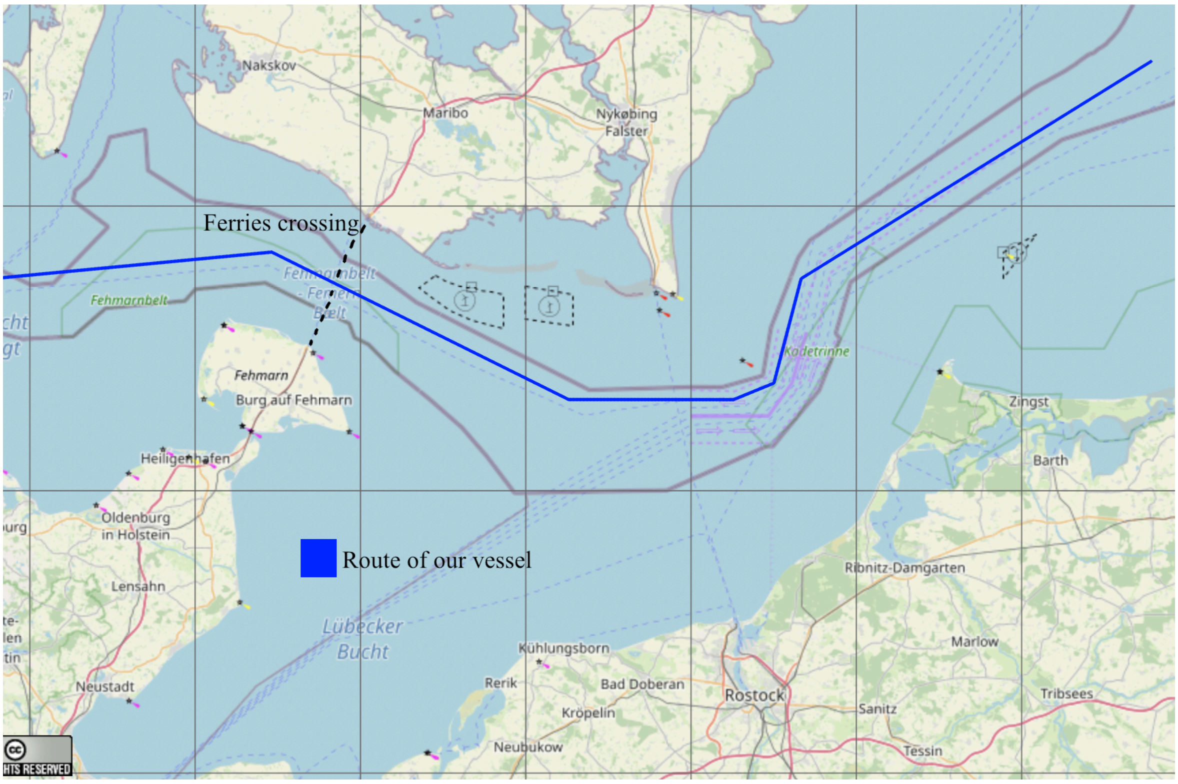


Figure 16. An overview of Kadetrenden and Fehmarn Belt. (Björk & OpenSeaMaps, 2021).

Shortly after the ferries the route turns west and southwest in the direction of Kiel. There are some radio reports to make when approaching, including a notice to the pilot station and Kiel Traffic VTS 2 hours before passing the Kiel lighthouse and when passing Friedrichsort lighthouse. Larger vessels take pilot at the Kiel lighthouse boarding station, but we are only required to have pilot when entering the Kiel-Holtenau locks, so our pilot is boarding just outside the lock. As we have little freeboard, no ladders are required, and the pilot has embarked at 23:05 on 25th of July.

2.3.6 Kiel Canal

Kiel Canal, or Nord-Ostsee-Kanal, is a 98-kilometre-long canal in Germany that connects the Baltic Sea with the North Sea. It is the busiest artificially made shipping lane in the world with approximately 90 ships transiting through each day, carrying a yearly total cargo of around 100 million tonnes. Each ship is assigned to a group, numbered between 1 and 6, based on their dimensions. This grouping determines for example if two ships can pass each other or do they need to meet at a specific siding area. (WSV, 2020)

The locks are wide and long and this time we have no other ships coming in, which means that there is plenty of space for manoeuvring even inside the lock. There are good floating fenders and there are linesmen giving the heaving line from ashore. We enter the north lock and put starboard side alongside, with one forward spring line and a head line and aft line. The roles are the same as in Saimaa Canal locks with the addition of the chief engineer being on the poop deck taking care of the aft line.

When we are moored in the Kiel-Holtenau locks, the master will go to the canal office to make a self-declaration for customs. In the case of many vessels, this is done by the agent and the master only needs to send the appropriate documentation via e-mail. However, our charterer prefers that we do it ourselves in exchange for a small bonus as they save the agency fees. The master needs to provide some documents, like the International Tonnage Certificate and a crew list, and details of the cargo onboard.

The pilot that took us into the lock will continue for the first half of the canal with us. Based on my experience, the pilots in the Nord-Ostsee-Kanal have very different approaches to their work. Some like to take over the navigation themselves and some refuse to take the wheel, stating that it is not allowed based on the regulations. On bigger vessels the pilot comes together with helmsmen who will take the wheel, but on smaller ships it is up to the master to decide how to deal with the issue. Depending on the officers' levels of experience, the master might either take over himself or have the OOW take care of the steering. In our case, we got a pilot not willing to steer himself and the second officer was not comfortable with hand steering the vessel in the channel, so the master chose to take over for the first half and have me steering the second half.

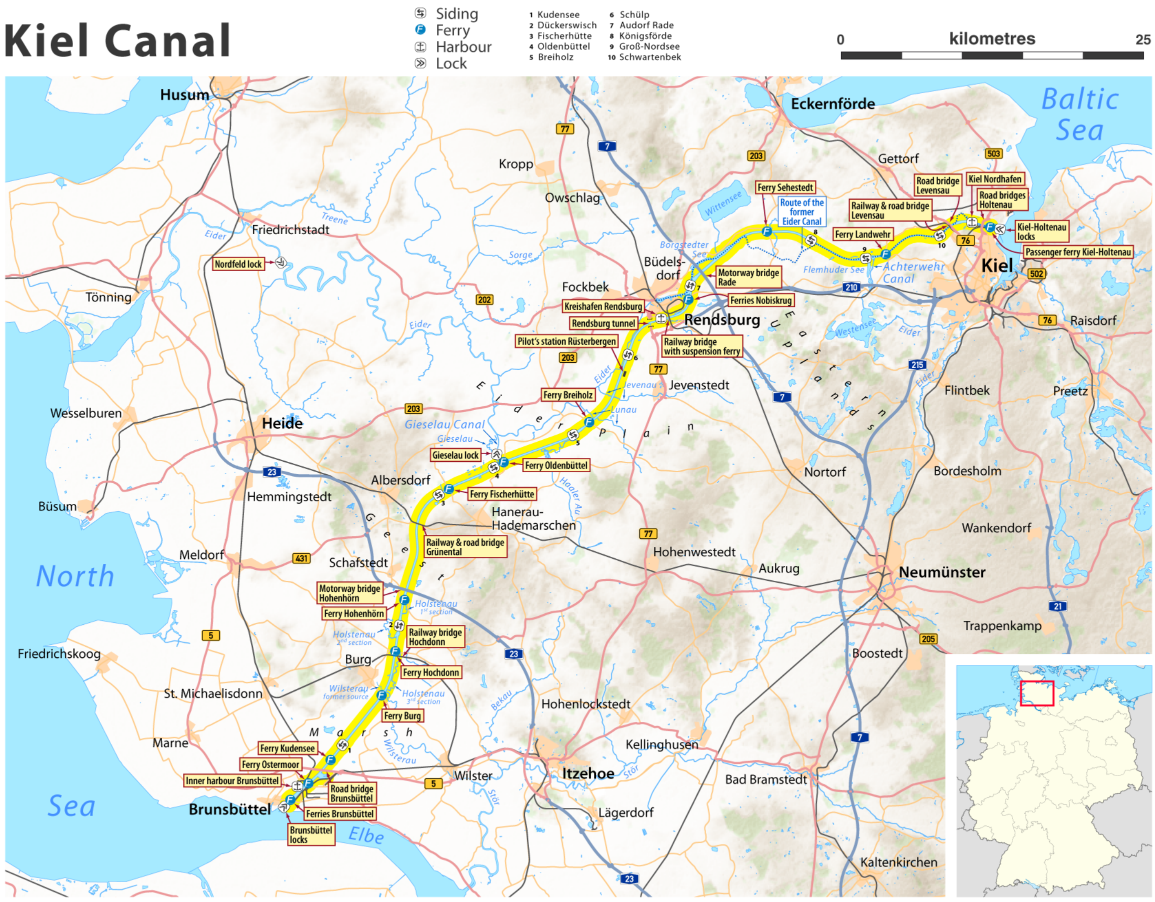


Figure 17. Kiel Canal with points of interest. (Dörrbecker, 2011).

Figure 17 illustrates the canal with points of interested highlighted. There are nine road or rail bridges on the way but none of them are any concern for us, since the fixed ones are all at least 42 meters above the water level. Ferries, supporting the road traffic, cross the canal in several places as well. The pilots take care of the radio traffic and inform the ferries of our movement along the channel, nut it is common practice for the ferries to give way for vessels passing through. There are ten siding places where larger vessels may meet, or a faster vessel may take over a slower one. These meetings and overtakes are pre-planned between the pilots and the monitoring traffic central.

Roughly halfway through the canal there is a change of pilot at the Rüsterbergen pilot station. The change is similar to the those on lake Saimaa. Relieving pilot boards and comes to the bridge for a quick handover, after which the relieved pilot disembarks, and the pilot boat clears off. As we were halfway through the master woke me up and I came to the bridge prepared to take the wheel. However, the second pilot had a different approach to the first one and wanted to steer himself. He told me that for him, it’s easier to be alert and maintain situation awareness by doing so.

We arrived at the other end of the canal in the morning of 26th. There was a little bit of congestion building up just before the locks, which was further highlighted by the road ferries crossing the canal. The pilot told me that the ferries keep clear of merchant ships but tend to pass at a very close distance which may sometimes cause irritation. We were able to fit in between some bigger vessels and went straight in the locks without much waiting. The procedure and team roles for the mooring in the locks were similar as in Kiel-Holtenau locks. When firmly moored at 06:50, the pilot disembarked, and the lock chamber started to drain from water.

2.3.7 River Elbe and North Sea

When the gates of Brunsbüttel lock were open we could proceed through river Elbe to the North Sea. The weather can be very rough in the North Sea and we have decided to always play it safe. So even when the weather forecast now looked promising, we put all the lines under deck after casting off and secured everything on deck. When in the Baltic Sea you don’t really have to worry about any tidal waters. But especially with small vessels on long rivers like Elbe it makes a huge difference whether you have the tidal current with you or against you. This also affects leaving and especially entering the locks as you may have to maintain higher speed, than usually necessary, in order to keep the vessel under control.

The high water for Cuxhaven was scheduled at around 08:00 ship time, meaning that the water was quite still when we left the lock, and soon the current had turned seawards thus giving us some extra speed. When leaving the lock, you make a radio call to Brunsbüttel Elbe Traffic and a few miles down the river you change over and report to Cuxhaven Elbe Traffic. On river Elbe there is a very clear two-way traffic scheme with buoyage and a virtual center line visible on the ECDIS screen, which you can see in Figure 18. VTS usually want smaller crafts to stay closer to the buoys, giving more space for bigger vessels to navigate closer to the center line. The VTS also provides an hourly traffic information which is helpful especially in heavy traffic so you can prepare to be overtaken by extra-large vessels.

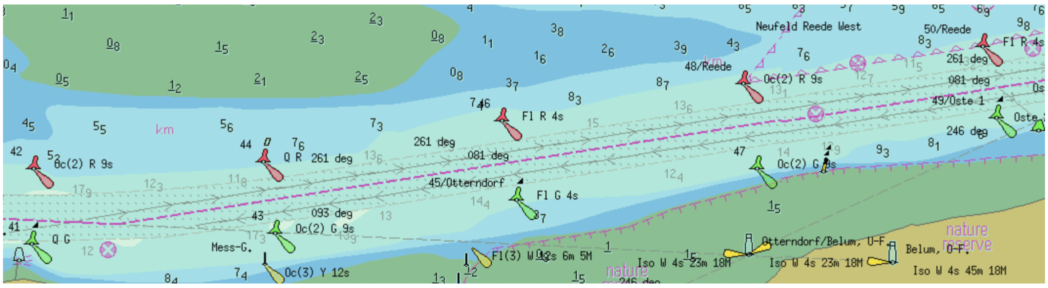


Figure 18. Traffic lanes, buoyage and center line on river Elbe. (Chartworld, 2021).

The speed was good all the way out and we passed Elbe light buoy at 12:00, reporting to German Bight Traffic. From here there are two different TSSs that you can follow when going west. We practically always take the southern one for two main reasons. First, the unexpected weather on North Sea might force us keep closer to the coastline. In strong northerly winds and swell we could follow the coastline south almost all the way outside of Amsterdam and from there cross over and follow the UK coastline. Now with fair weather we could exit the TSS at its west end as intended and make our way between the oil platforms. You can see an overview of the North Sea and the two TSSs in Figure 19. The blue line represents our intended and actual route while the red line represents a possible deviation in case of strong weather.

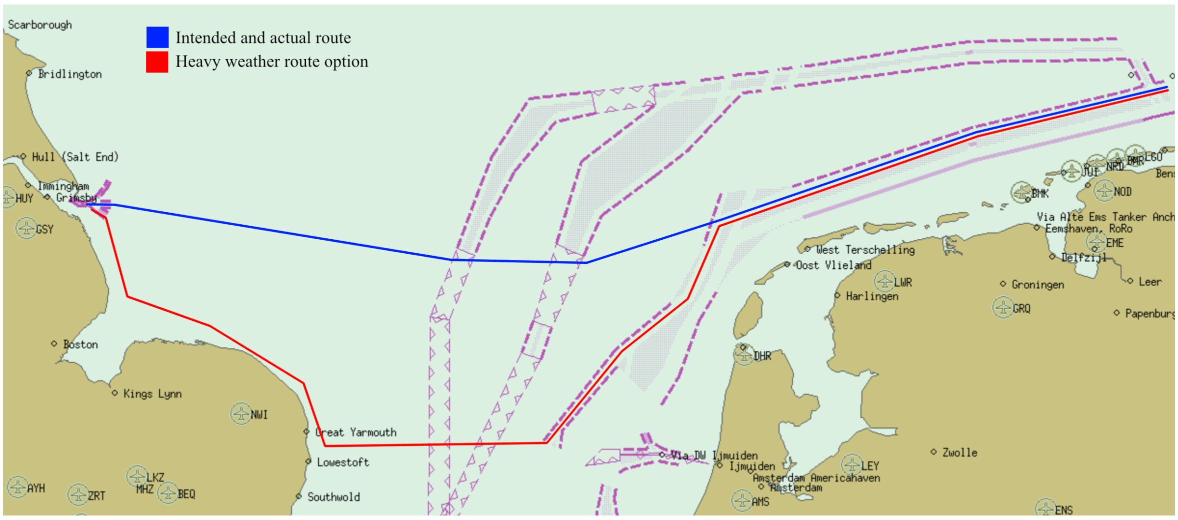


Figure 19. The Traffic Separation Schemes in the North Sea and two different routing options. (Björk & Chartworld, 2021).

The other reason for taking the southern TSS is that we have no satellite internet and keeping close to shore is the only way for us to maintain internet signal. The master might need to send a daily report or the agent could try to inform us about some changes in schedules, we would not be able to send or receive any of those e-mails if we were to take the northern TSS. The northern TSS is some miles shorter but our master sees it as not worth it and I think the whole crew can agree.

When crossing the North Sea an important thing to bear in mind is the vast amount of oil rigs in the area. It is important to always keep a safe distance to the rigs. There can, e.g., be a supply vessel exiting the oil field which could be hard to notice at first. There is a safety zone of 500 meters to any oil rig that you should not interfere with. This is the maximum distance a safety zone can be according to United Nations Convention on the Law of the Sea (UNCLOS) but according to a document by Shipping Advisory Board Northsea it is only meant to protect the structure and not to be taken as a safe passing distance. There are no direct regulations about the safe passing distance but, as an example, the aforementioned document states that by combining AIS data and Dutch Coast Guard reports, studies have shown 90% of vessels drift for approximately one hour when Not Under Command. As an average the same studies find this distance to be 1,7 nautical miles. (Shipping Advisory Board Northsea, 2009).

The document is, however, meant mainly as a guidance in planning fairways and not necessarily as guidelines on manouvering. When there are no such fairways or standard routening in the area you are crossing you have to pay extra attention both in planning and executing the route. When approaching the coast of UK, the fishing activities increase significantly. One should consider to have an additional lookout on the bridge even during daytime since in my experience the buoys marking the fishing equipment can be very hard to spot especially in some swell.

2.3.8 Humber Approach and Arrival

When we are four hours from the Spurn Head pilot boarding station (see Figure 10), we start trying to make contact with our VHF radio to the VTS for reporting our ETA. When approaching from open sea, at least with our equipment and in below fair weather conditions regarding radio transmission, this is mostly useless and we may get contact around two hours before arriving at the coastline. The pilotage on river Humber is compulsory for us and the pilot boarding time depends on the tides. Even if we could go into Hull with our present draught disregarding the tidal changes, there might be vessels heading for Goole or somewhere else further up Humber river, which needs to take advantage of the high water, so congestion is fairly common.

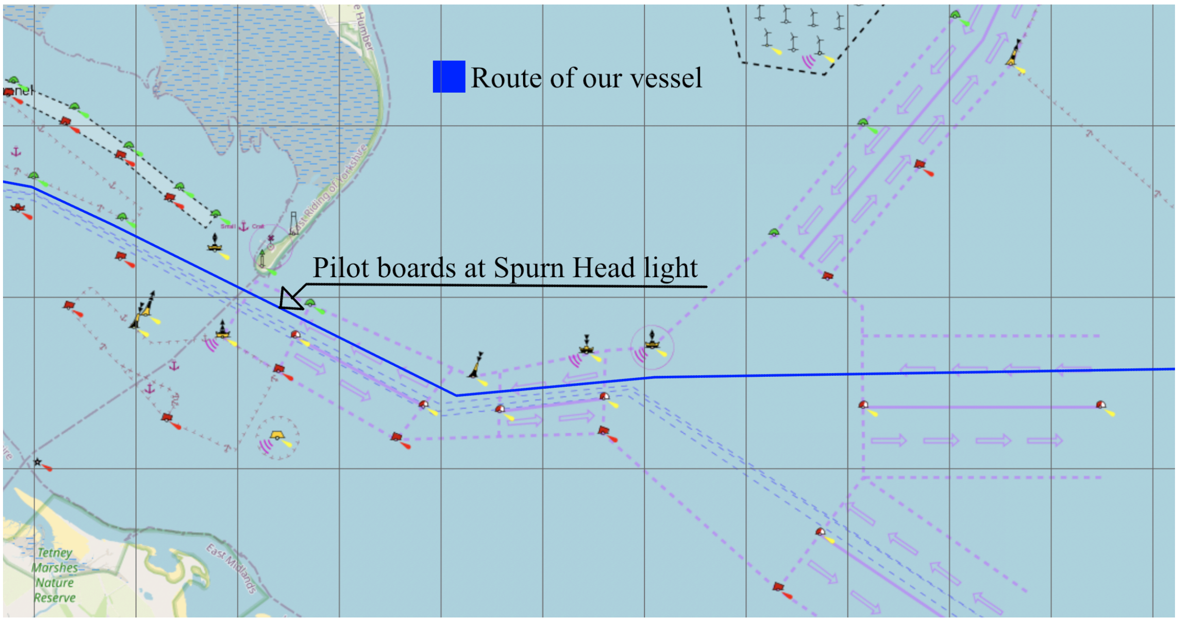


Figure 20. Spurn Head lt and the entrance to river Humber. (Björk & OpenSeaMaps, 2021).

This time we were lucky to get the pilot on arrival and there was no need for adjusting the speed or go to anchor. Before taking the pilot there is a couple of reports to be made to Humber VTS but then the pilot takes over the radio traffic as well as the wheel. According to the ship's logbook the pilot boarded on 27th of July at 23:00. Again, no pilot ladder was needed due to our low freeboard.

On the river Humber there are not many specialities apart from the tides and currents. The pilot takes care of the navigation and the OOW acts as a lookout and gives advice on using equipment if necessary. The trip from the pilot station to Queen Elizabeth lock takes a bit more than two hours and we are in the vicinity just after 01:00. The entrance to the lock is tricky especially with strong current. You have to turn the vessel over 90 degrees to starboard just before the lock and have enough speed not to be carried away by the current. The pilots are, however, experienced and have knowledge about the local circumstances and can give very precise advice to the master. We entered the lock without a problem and moored port side alongside with one spring line and head line in forward and one aft line. After the lock gates behind us had closed and the ones in front of us opened, we made our way from the lock chamber the King George Dock basin and Quay #11.

The mooring procedure at berth differs from the one in the locks that you might not have the space to approach parallel to the quay. This time we approached the quay on our port side, in roughly a 45-degree angle and at very slow speed. You can see the approach illustrated in Figure 21. When approaching, the chief officer is in the forward repeating the distances to quay by radio to the master and if necessary, the second officer will do the same in aft. AB takes care of the lines in forward and the chief engineer in the aft, with the help of the officers. When the vessel is close enough, the AB will throw the heaving line ashore and the linesmen will reel in the forward spring line which is attached to it. The master may give a kick aft with the engines to further slow down the vessel. With a right-handed propeller, like ours, this will also push the aft of the vessel closer to the quay and the forward away from it. When properly planned and executed, this manoeuvre results the ship in approaching the quay more parallelly at a very slow speed, giving room for corrections if needed. The master may use the bow thruster to counter the forward moving away from the quay. When the desired position is getting closer, the master orders to make fast the spring line and he uses that line to steer the ship steadily alongside the berth. Then we put the lines as we did in the locks, but an additional headline in the forward and a spring line in the aft. The logbook reads all fast in Hull at 02:15 and the discharging would begin in the morning.

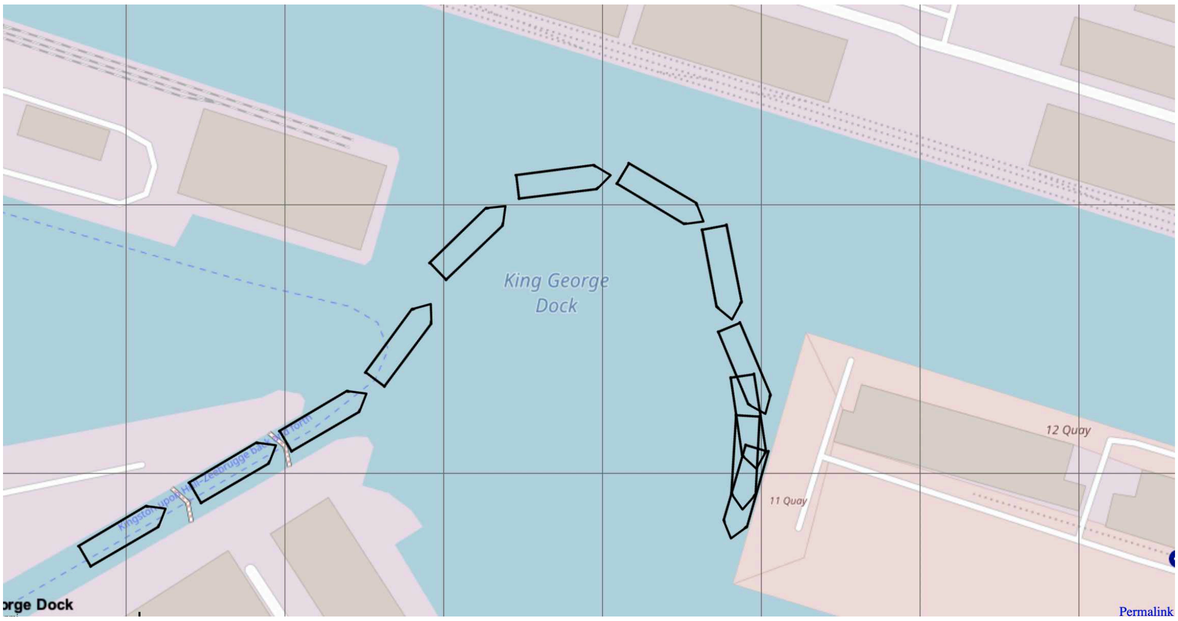


Figure 21. Approaching Quay #11 in King George Dock. (Björk & OpenSeaMaps, 2021).

2.4 Discharging

Before the discharging could commence, we needed to remove the lashings and tarpaulins. This was done by vessel's crew and assistance was received by stevedores. I agreed with the foreman to discharge the second layer from midship to aft and then continue towards the fore of the ship. Stevedores started discharging at 10:30 local time and discharged two to four packs of timber with each lift and the decks were empty within two hours.

We open the cleats and wedges securing the hatch and use the gantry crane to stack the hatches in positions #8 and #5. Discharging the hold begins from forward and half of the cargo height is emptied until hatch number five. The hatches are then stacked in positions #1 and #3 and the aft part could be discharged completely. However, we closed the hatches for the night as the stevedores did not work beyond 18:00 local time. At this time about half of the cargo in the holds had been discharged.

On the following morning we started by moving the hatches back to positions #1 and #3 and finished discharging the aft part of the hold. Finally, the hatches were moved back in positions #5 and #8 so that the rest of the cargo in the forward part of the hold could be discharged. The discharging operation took about fourteen hours total. We filled the forepeak ballast water tank only after the cargo operations were finished. This is because when the tank is pumped full, it will overflow on the forecastle through the replacement air pipe and the water would end up in the cargo hold, as there was no hatch in position #1, making the cargo wet.

Figure 22. Folded tarpaulins laying on the berth. (Björk, 2020).

Discharging the cargo was a much simpler process compared to loading. No draught surveys were needed and the ballast operations for this particular discharging were minimal. The only thing that caused some extra work was the tarpaulins, lashing equipment and the timber slings. The lashing belts and tarpaulins were taken ashore for folding (see Figure 22), as there was more space on the quay, and then stored under the forecastle. Some vessels are fitted with a hatch leading to the lashing store, which makes it possible to lower a large number of slings by crane. The lashing store of our vessel was also located under the forecastle as a separate space, but the slings would have to be manually lowered through the entrance because there was no hatch leading directly to the store from deck. This meant that we needed to make bundles of around ten slings to be able to handle them while maintaining reasonable vitality. We had done this once before so that the stevedores lifted all the slings on top of the hatches after discharging was completed and we bundled them ourselves before lowering into the stores.

This time we asked the stevedores to bundle them as they removed the slings from the timber packs, and they kindly agreed. After completion, the crane lifted the prepared bundles on top of the hatches and we could lower and store them as they were, saving us about three hours of work.

3 Analysis

This section of the thesis will analyse some aspects of the voyage that I would like to point out. It is very hard to measure performance with exact numbers and therefore the analysis will mostly focus on comparing the choices we made to alternative ones and discussing the differences. In some cases, it is impossible to determine whether one alternative is absolutely better than the other due to lack of data and resources. However, the differences will still be explained briefly if I see them as important aspects on voyage performance.

3.1 Route planning and bunkering

When determining whether or not the route was optimized to a satisfactory extent, the most obvious factor at play is the length. Our route was 1342 nautical miles long and is very close to the shortest option. If we would not have had to anchor for bunkering and would have taken the northern route on the North Sea, the route would have been 1322 nautical miles long. This is only 20 nautical miles, or approximately 1,5 %, difference in length. If we compare time, we can see from the logbook that our trip took about 165 hours which means that the average speed was 8,13 knots and if we take away the three hours that we were at anchor, the average speed rises to 8,28 knots. If we use this average speed to calculate the duration of the shorter trip, we end up with a total of 159 hours and thirty minutes. This is five and a half hours shorter on an almost weeklong trip, making the difference to 3,3 % of the total duration.

I have no data of the bunker prices from suppliers in Puhos compared to the prices from suppliers in Tallinn. This makes it impossible to compare would it have been more effective to bunker in Puhos during loading, but we may, however, safely assume that the prices in Tallinn were even slightly lower, since the charterer chose that option. With the delay in duration together with the extra 20 nautical miles caused by the anchoring making such a small difference in the total length and duration of the trip, it is extremely unlikely in my opinion, that the saved time would make up for the higher bunker price in Puhos. Even if the bunker prices in Puhos and Tallinn would have been exactly the same, the economical aspect of the delay remains very small. One could argue that if similar decisions to bunker at anchor were made over time, it would result in several days' worth of yearly delay, which in turn could have been used to perform an additional trip and profiting from that. However, this thesis focuses only on a single trip and the role of speculation in the mentioned hypothetical case is of such calibre that I will not go any deeper into it. With the information I have and to my best knowledge, the charterer made the right decision in sending us to bunker at Tallinn Roads compared to bunkering in Puhos.

3.2 Cargo operations and intake

The cargo amount was 3167,66 cubic meters according to the bill of lading. Based on documentation from previous voyages I found that this was the best cargo intake for timber package voyages this vessel had ever documented. The previous cargos had mostly intakes between 3050-3100 cubic meters with an average of 3064,8 cubic meters meaning our intake was 3,36 percent above average. This was satisfying news for the charterer.

The reason for the extra intake is partly due to the fact that the vessel has loaded in Puhos several times under the same foreman, meaning that the experience of the stevedores will contribute to the maximum intake. Another important reason is that we decided not to place the gantry crane in its regular position, but secure it as aft as possible, giving more space for deck cargo. This turned out to be problematic when taking pilot from the starboard side. The gantry crane has ladders attached to its starboard side and being placed so far aft it partly blocked the path from the pilot gate to the main deck. Many pilots complained that it was unnecessarily hard to get past the gantry crane and at one point we removed the ladders from the gantry crane's side to ease the matter.

Loading of the cargo took about fifteen hours including breaks and one 90-minute stop caused by a forklift's broken battery charger which needed to be replaced. Discharging took about fourteen hours during two workdays. Based on documentation from previous voyages these stood well in line with the average loading and discharging times. The 90-minute delay in Puhos was implemented into the lunch break of the stevedores, and they could do some level of preparations while the charger was replaced so in reality the delay was maybe worth 30 minutes. In Hull it seems to have taken two workdays every time the vessel was discharging there so it's pointless to start even calculating the minutes. The bundling of the timber slings by the stevedores, however, saved us some hours between completion of discharging and time of departure.

4 Conclusions

Based on the analysis the voyage performance seemed to be good. The route was optimized to a reasonable extent, the only apparent delay was the anchoring and bunkering at Tallinn roads but that was accounted for by the cheaper bunker price, some time was saved thanks to some helpful stevedores in Hull pre-bundling the slings and a vessel-specific record intake of cargo was loaded. None of the cargo was lost during the voyage and no claims were made by any party to my best knowledge.

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Appendix A – Displacement and Stability Calculations

The displacement and stability calculations are often in the present day done using either a class approved stability program or with the help of an Excel spreadsheet. The idea is still the same and I will explain the calculations briefly using the same figures as in the actual calculations described in my thesis. I will use the figures of the initial and final draft surveys and exclude the intermediate draught survey to simplify the matter. I will explain the principle of the righting curves but not go into detail in calculating them. A detailed description of the criteria and theory behind the calculations can be found in the Code on Intact Stability for All Ships Covered by IMO Instruments (IS Code) released in 1993 and the revised version International Code on Intact Stability (2008 IS Code).

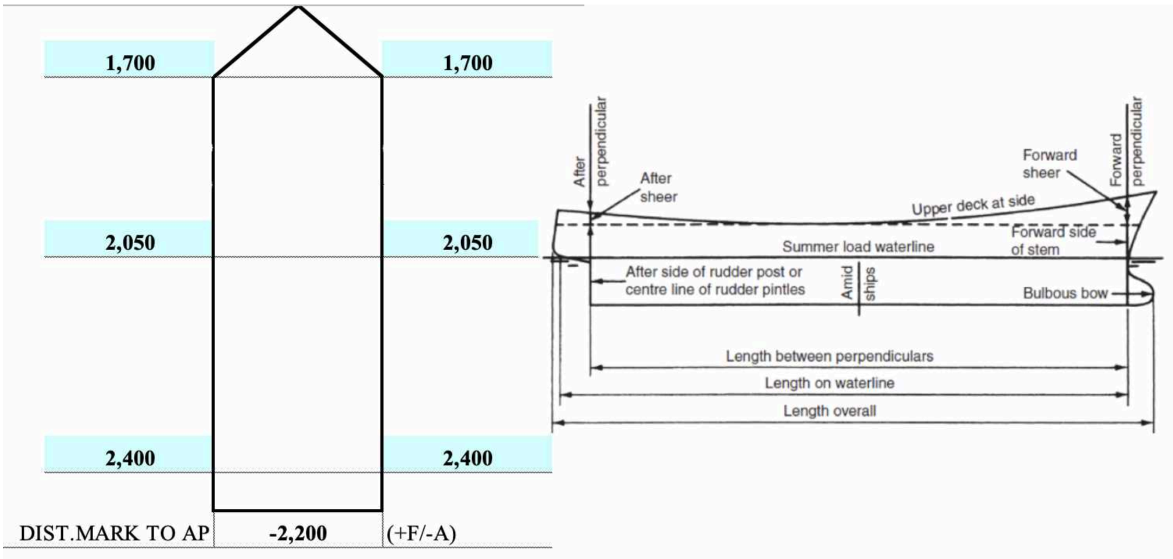


Figure A-1. Measured apparent initial draughts and illustration of perpendiculars (Björk & Chakraborty, 2021).

In Figure A-1 you can see the measured apparent initial draughts of our vessel and an illustration clarifying the matter with perpendiculars. Apparent draughts mean that they are not necessarily measured at correct relation to the vessel's perpendiculars, which are the basis for our calculations. The forward perpendicular is an imaginary vertical line at the point where the bow and waterline meet if the vessel would be submerged to the summer load line. The aft perpendicular is an imaginary vertical line in the middle of the rudder stock. The actual forward and aft draughts are measured from the perpendiculars and midship draughts are measured exactly between the perpendiculars.

Our forward draught marks are located at the forward perpendicular and our midship draught marks are located exactly between the perpendiculars. This means that the forward and midship apparent draughts are the same as actual draughts and they do not need to be corrected. However, the aft draught marks on our ship, as you see in Figure A-1, are located 2,2 meters aft from the aft perpendicular and the figure needs to be corrected. Whether it is +2,2m or –2,2m in the calculation depends on the locations of the draught marks in reference to the aft perpendicular. If the draught marks are located in front of the aft perpendicular, we use + and if they are aft of the perpendicular, we use -. So, in our case it is -2,2 meters. For the correction calculations we need the observed trim (apparent aft draught – apparent forward draught, in our case 0,7 meters), length between the perpendiculars (LBP, in our case this is 77,2 meters) and the distance from draught marks to aft perpendicular (D AP, in our case -2,2m).

$$Correction = \frac{trim * D\ AP}{LBP - D\ AP} \qquad Correction = \frac{0{,}7m * -2{,}2m}{77{,}2m - -2{,}2m} = -0{,}019m$$

That means the actual draught in aft is 2,40m – 0,019m = 2,381m and this is what we will use in our calculations. To summarise our figures:

Actual draught in forward (dF)	= 1,70 m
Actual draught in midships (dM)	= 2,05 m
Actual draught in aft (dA)	= 2,381 m
Actual trim	= 0,681 m
Length between perpendiculars (LBP)	= 77,2 m

Next step is to calculate the mean draught. To decrease the effect of hull deformation, hogging, sagging and small human errors in reading the draughts, we use the so called mean of means. The formula for mean of means is:

$$Mean\ of\ means = \frac{(dM\ x\ 6) + dA + dF}{8}$$

$$Mean\ of\ means = \frac{(2{,}05m\ x\ 6) + 2{,}381m + 1{,}7m}{8} = 2{,}047625m$$

HYDROSTATIC PARTICULARS
BIJLSMA-TRADER 2500 Yardno. 665

14-09-1993 09:22 Trim = 0.000 m

Draught from US keel m	Displ. in freshw ton	Displ. in seaw. ton	Immer-sion seaw. ton/cm (TPC)	Moment change trim Tonm/cm (MCT)	LCB from APP m	LCF from APP m	KM transv. m
1.920	1285.14	1317.27	7.38	33.11	41.038	40.000	6.181
1.940	1299.53	1332.02	7.38	33.21	41.027	39.977	6.141
1.960	1313.94	1346.79	7.39	33.30	41.015	39.958	6.102
1.980	1328.37	1361.58	7.40	33.39	41.003	39.938	6.063
2.000	1342.81	1376.38	7.41	33.48	40.992	39.920	6.026
2.020	1357.26	1391.19	7.41	33.58	40.980	39.898	5.989
2,048 — 2.040	1371.73	1406.02	7.42	33.67	40.969	39.876	5.954
2.060	1386.21	1420.87	7.43	33.76	40.957	39.857	5.919
2.080	1400.71	1435.72	7.43	33.86	40.946	39.835	5.886

Figure A-2. Hydrostatic particulars table from the stability booklet. (Björk, 2021)

Let us round up and say our mean of means is 2,048 meters. Now we can take the stability booklet and search for the displacements which corresponds to our mean draught. As you can see in Figure A-2, the table does not show values for a draught of 2,048 meters. We land somewhere between 2,040 meters and 2,060 meters. This means that we have to interpolate the values to reach a displacement figure corresponding our mean of means. The interpolation on our vessel is done in a an excel file but I will clarify the procedure.

In Figure A-3 you can see the interpolation table taken from the excel sheet. In the upper row we input the values for draught 2,040 from the hydrostatics table and in the lower row we do the same for draught 2,060. We also know our mean of mean draught, which we can put in the first column of the middle row. Then we can start interpolating.

	Dens.in Table	**1,025**		
	DRAFT	DISPL. SW	LCF	TPC
LOWER DFT	2,040	1 406,020	39,876	7,42
INITIAL M/O/M	**2,048**	**1 411,960**	**39,868**	**7,42**
UPPER DFT	2,060	1 420,870	39,857	7,43

Figure A-3. Interpolated values for draught 2,048 meters. (Björk, 2021).

The interpolation formula we are using is $y = \frac{(y2-y1)}{(x2-x1)} * (x - x1) + y1$

If we interpolate the displacement first, the y represents the displacement for our mean of mean draught. The upper row displacement figure is represented by y1 and the lower row by y2. Same goes for the draughts: x represents mean of mean draughts, x1 upper row draught and x2 lower row draught. If we take the numbers from the table in Figure A-3, we get the following equation:

$\frac{(1420{,}87-1406{,}02)}{(2{,}060-2{,}040)} * (2{,}048 - 2{,}040) + 1406{,}02$ = 1411,96

So, the displacement for draught 2,048 meters is 1411,96 metric tonnes. If you look at Figure A-2, you can see the underlined text Trim = 0,000 m. This means that the tables are valid as such only when the vessel is at even keel. According to the Archimedes principle a floating ship displaces its own weight worth of water. We have now calculated the displacement for mean draught as it would be in even keel with the center of flotation at midships. However, when the ship is in trim condition, the center of flotation is moving away from the midship. To correct for this distance, we have to apply something we call the 1st trim correction. We will use a formula that converts this distance into metric tonnes, which we can then apply to our displacement figure as a correction. The formula may seem complex at first but the only new value we have to calculate is the distance from the actual midship to the longitudinal center of flotation (LCF) as interpolated in Figure A-3. The actual midship in our calculations is the length between perpendiculars divided by two. The difference between this figure and our LCF is:

$$39.868m - \frac{77{,}2m}{2} = 1{,}268m$$

Our trim is 0,681 meters but, in the formula, we will use centimetres, which means our figure will be 68,1 centimetres. We will also need the TPC value from Figure A-3, which is 7,42. Now, the formula for 1st trim correction is:

"TPC" * Distance between "LBP/2" and "LCF" * "Trim" in cm / "LBP"

Enter the values:

7,42 t/cm* 1,268m * 68,1cm / 77,2m = 8,2995…t ≈ 8,30t

You don't have to worry about the sign of your result as we will apply a different rule on determining whether it is "+" or "-". If the vessel is in aft trim and the LCF is forward of midships, the sign will be "–", and if the LCF is aft of midships, the sign will be "+". If the vessel is trimmed forward, the opposite is true. Here is a quick table for determining the sign of the correction.

Trim	LCF fwd	LCF aft
Aft	-	+
Fwd	+	-

In our case the LCF is forward of midships and we are in aft trim, which means the sign of our correction is “-“. Thus, our 1st trim correction is -8,30 metric tonnes. We will apply this to our displacement figure, but first we need to calculate the 2nd trim correction.

The 2nd trim correction is applied because of the vessel’s non-symmetrical shape. The stability booklet will show the LCF value for zero trim, and the waterplane area changes as the vessel is trimmed. This is creating a slight misplacement of the LCF, which is then corrected by the 2nd trim correction.

For the formula, in addition to the figures we already have, we need to calculate the difference in moment to change trim (MTC) over 1-meter mean draught, which is measured in metric tonnes needed for one centimetre of change in trim. This is done by checking the hydrostatic tables for values corresponding our mean draught + 0,5 meters and our mean draught – 0,5 meters. Again, our draughts are not exactly as presented in the hydrostatic tables, so we need to interpolate using the higher and lower values. In Figure A-4 you can see an outtake from the Excel sheet we are using, with the MTC values already interpolated. Then we calculate the difference between those two MTC values. The resulting value, let’s call it DMZ, is then inserted into the formula.

1st MTC	2,540	36,31	**2nd MTC**	1,540	31,22
Corr.Draft +0,5	**2,548**	**36,36**	Corr.-0,5	**1,548**	**31,26**
	2,560	36,43		1,560	31,31

Figure A-4. MTC values for mean draught + 0,50m and mean draught – 0,50m ready interpolated. (Björk, 2021).

We already went through the process of interpolation and it is exactly the same here. After the interpolation we will see that the MTC value for mean draught + 0,50 meters is 36,36 metric tonnes per centimeter and the MTC value for mean draught – 0,5 meters is 31,26 metric tonnes per centimeter. The difference, DMZ, is then 36,36 t/cm – 31,26 t/cm = 5,10 t/cm. In the formula we ignore the "per centimeter" and use only tonnes. Now we have everything we need for the formula:

$$2nd\ trim\ correction = \frac{Trim^2}{LBP} * 50 * DMZ$$

If we input our values, we get:

$\frac{0{,}681^2\ m}{77{,}20\ m} * 50 * 5{,}10t$ = 1,53185…t ≈ 1,53t

The 2nd trim correction is therefore 1,53 metric tonnes. Note that in this formula we input the trim value in meters, as opposed to centimeters in the formula for the 1st trim correction. This is important as it will greatly affect the result. This is, however, fairly easy to notice as the result would be illogical. For demonstrative purposes, I calculated the second trim correction with using centimeters as trim value and got a result 15318,53 metric tonnes. This is more than six times the deadweight of our vessel, so we know immediately that something is wrong with the equation.

Now we may apply both trim corrections to our displacement figure and get the displacement corrected for trim:

1411,96t – 8,30t + 1,53t = 1405,19t

The last correction we apply is the correction for dock water density. We measure the dock water density with a hydrometer to be exactly 1,000 t/m^3. Now if you look at Figure A-2, you may notice that there is a column for displacement in fresh water. This is actually measured at 1,000 t/m^3 density so we could have used that figure, interpolated it to our mean draught and applied the trim corrections and got the same result. However, in most cases the density is somewhere between 1,000 and 1,025, in which case we can use the following simple formula to correct for dock water density:

$$Displacement_{actual} = \frac{Displacement_{Corrected\ for\ trim}\ *\ Actual\ density}{Density\ used\ in\ hydrostatic\ tables}$$

If we input our values, we get:

$$\frac{1405{,}19t * 1{,}000\ t/m^3}{1{,}025\ t/m^3} = 1370{,}917073t \approx 1370{,}92t$$

After all the corrections we apply, our final displacement figure is 1370,92 metric tonnes. The next step is to deduct all the so-called variable weights and the lightship weight. We are then left with a figure that is called constant. This figure represents the change in actual light ship weight over time, resulting from, e.g., sediments in ballast tanks, modifications to the ship and the accumulation of different stores. The constant changes over time and the vessel's crew are aware of what the constant usually will be. If the calculated constant in a draught survey is close to this figure, the calculations can be deemed to be reliable. On our ship the constant is usually around 27 metric tonnes.

We have the ballast tank figures from the sounding of the empty tanks, and we have overflown the full tanks to be sure that the conditions are as presumed. The rest of the variable weights we will get from the chief engineer's tables and the light ship can be found in the stability booklet. You can see the list of our variables in Figure A-5. Pay special attention to bunker figures since the chief engineer usually notes them in cubic meters whereas we need the metric tonnes for our calculations. For conversion you can ask the chief engineer for the specific density but for Marine Gasoil, which we use, the density will be close to 0,84 tonnes per cubic meter. In Figure A-5, the conversion has already been made.

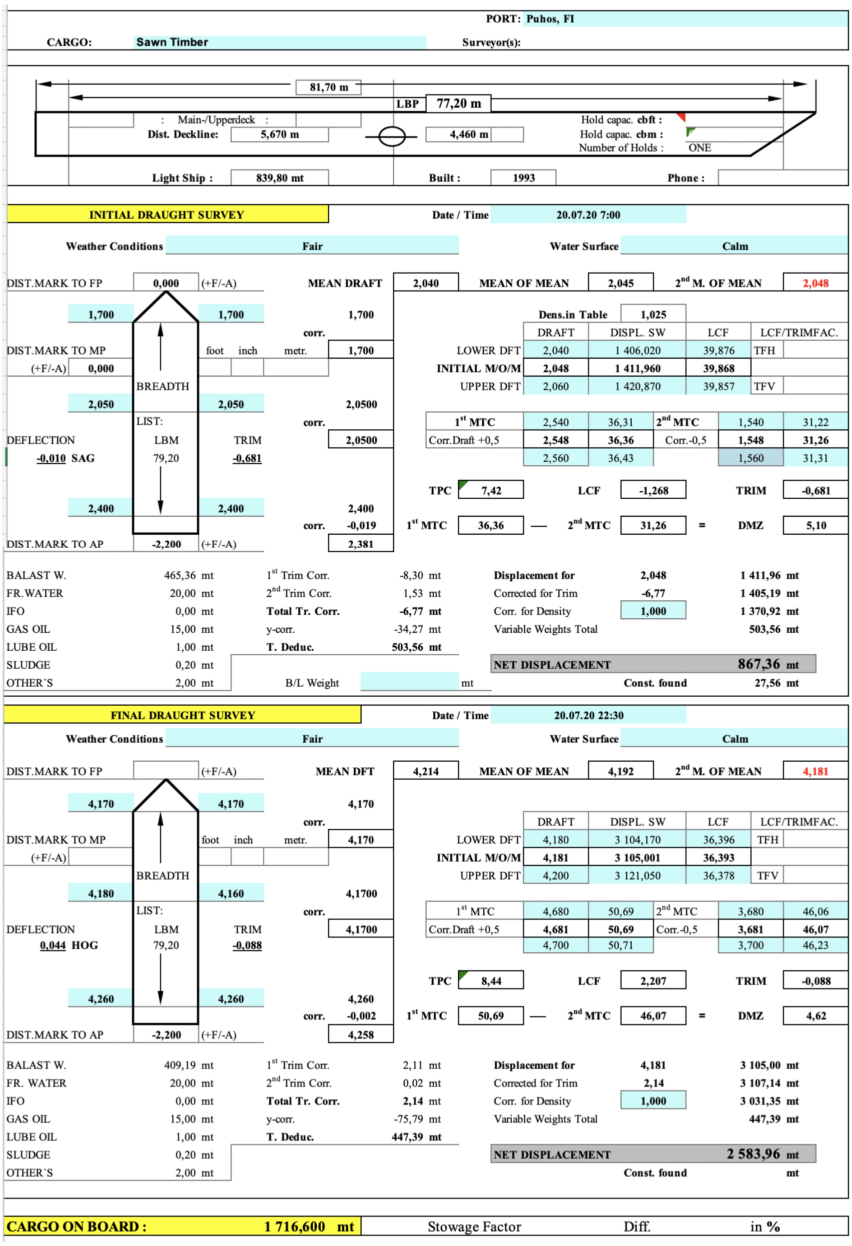
Ballast	465,36	mt
Fresh Water	20,00	mt
Marine Gas Oil	15,00	mt
Lube Oil	1,00	mt
Sludge	0,20	mt
Dirty Water / Other	2,00	mt
Total Deduction	**503,56**	mt

Figure A-5. The variable weights table used for our calculations. (Björk, 2021).

Our lightship weight is 839,80 metric tonnes and total variables, taken from the variable weights table, is 503,56 metric tonnes. If we deduct these figures from our corrected displacement figure, we get a constant of 27,56 metric tonnes.

1370,92t – 839,80t – 503,56t = 27,56t

This is very close to the 27 metric tonnes and therefore we can conclude that the measurements and calculations were successful. When completed loading, we do the exact same procedure with the final draughts. We get a net displacement figure, from which we will further deduct the value of constant, and the resulting figure represents the amount of cargo onboard. In the final draught survey, you have different draughts and may have different variable weights, but the procedure is otherwise exactly the same. In Figure A-6, you can see the spreadsheet with the initial and final calculations as presented in Excel. At the bottom left-hand corner, you can see the final cargo figure to be 1716,60 metric tonnes.


PORT: Puhos, FI
CARGO: Sawn Timber
Surveyor(s):
81,70 m
LBP 77,20 m
: Main-/Upperdeck :
Dist. Deckline: 5,670 m
4,460 m
Hold capac. cbft :
Hold capac. cbm :
Number of Holds : ONE
Light Ship : 839,80 mt
Built : 1993
Phone :

INITIAL DRAUGHT SURVEY			Date / Time	20.07.20 7:00		
Weather Conditions	Fair		Water Surface	Calm		
DIST.MARK TO FP	0,000 (+F/-A)	MEAN DRAFT	2,040	MEAN OF MEAN	2,045	2nd M. OF MEAN 2,048
	1,700	1,700	1,700	Dens.in Table	1,025	

	DRAFT	DISPL. SW	LCF	LCF/TRIMFAC.
LOWER DFT	2,040	1 406,020	39,876	TFH
INITIAL M/O/M	2,048	1 411,960	39,868	
UPPER DFT	2,060	1 420,870	39,857	TFV

1st MTC	2,540	36,31	2nd MTC	1,540	31,22
Corr.Draft +0,5	2,548	36,36	Corr.-0,5	1,548	31,26
	2,560	36,43		1,560	31,31

DIST.MARK TO MP (+F/-A) 0,000; foot inch metr. 1,700
BREADTH
2,050 | 2,050 | 2,0500
LIST: corr. 2,0500
DEFLECTION -0,010 SAG; LBM 79,20; TRIM -0,681
2,400 | 2,400 | 2,400 corr. -0,019 2,381
DIST.MARK TO AP -2,200 (+F/-A)
TPC 7,42 | LCF -1,268 | TRIM -0,681
1st MTC 36,36 — 2nd MTC 31,26 = DMZ 5,10

BALAST W.	465,36 mt	1st Trim Corr.	-8,30 mt	Displacement for	2,048	1 411,96 mt
FR.WATER	20,00 mt	2nd Trim Corr.	1,53 mt	Corrected for Trim	-6,77	1 405,19 mt
IFO	0,00 mt	Total Tr. Corr.	-6,77 mt	Corr. for Density	1,000	1 370,92 mt
GAS OIL	15,00 mt	y-corr.	-34,27 mt	Variable Weights Total		503,56 mt
LUBE OIL	1,00 mt	T. Deduc.	503,56 mt			
SLUDGE	0,20 mt			NET DISPLACEMENT		867,36 mt
OTHER´S	2,00 mt	B/L Weight	mt	Const. found		27,56 mt

FINAL DRAUGHT SURVEY			Date / Time	20.07.20 22:30		
Weather Conditions	Fair		Water Surface	Calm		
DIST.MARK TO FP	(+F/-A)	MEAN DFT	4,214	MEAN OF MEAN	4,192	2nd M. OF MEAN 4,181
	4,170	4,170	4,170			

	DRAFT	DISPL. SW	LCF	LCF/TRIMFAC.
LOWER DFT	4,180	3 104,170	36,396	TFH
INITIAL M/O/M	4,181	3 105,001	36,393	
UPPER DFT	4,200	3 121,050	36,378	TFV

1st MTC	4,680	50,69	2nd MTC	3,680	46,06
Corr.Draft +0,5	4,681	50,69	Corr.-0,5	3,681	46,07
	4,700	50,71		3,700	46,23

DIST.MARK TO MP (+F/-A); foot inch metr. 4,170
BREADTH
4,180 | 4,160 | 4,1700
LIST: corr. 4,1700
DEFLECTION 0,044 HOG; LBM 79,20; TRIM -0,088
4,260 | 4,260 | 4,260 corr. -0,002 4,258
DIST.MARK TO AP -2,200 (+F/-A)
TPC 8,44 | LCF 2,207 | TRIM -0,088
1st MTC 50,69 — 2nd MTC 46,07 = DMZ 4,62

BALAST W.	409,19 mt	1st Trim Corr.	2,11 mt	Displacement for	4,181	3 105,00 mt
FR. WATER	20,00 mt	2nd Trim Corr.	0,02 mt	Corrected for Trim	2,14	3 107,14 mt
IFO	0,00 mt	Total Tr. Corr.	2,14 mt	Corr. for Density	1,000	3 031,35 mt
GAS OIL	15,00 mt	y-corr.	-75,79 mt	Variable Weights Total		447,39 mt
LUBE OIL	1,00 mt	T. Deduc.	447,39 mt			
SLUDGE	0,20 mt			NET DISPLACEMENT		2 583,96 mt
OTHER´S	2,00 mt			Const. found		mt

CARGO ON BOARD : 1 716,600 mt | Stowage Factor | Diff. | in %

Figure A-6. Final displacement calculations. (Björk, 2021).

Calculating stability is not that much more complex but there are certain things where you need to be more precise compared to the displacement calculations. For example, in the displacement calculations we use the weight of the ballast water as such but in the stability calculations we need to insert the weights, longitudinal and vertical centers of gravity (LCG and KG respectively) and free surface moments for each ballast tank separately. I will explain the effect of free surface moments later.

Before we start calculating, we need to make a table of all weights with their KG, LCG and free surface moment, if applicable, that we have onboard the ship and including the light vessel itself. The weights we already know from the draught survey and sounding of the tanks. Rest of the information is in the hydrostatic tables and stability booklet. In Figure A-7 you can see a list of weights with necessary information. The figures for cargo are determined based on where the cargo is placed and how high the stack is. Higher cargo means higher KG. For example, if the hold is full and the weight is spread evenly, the KG would be hold height divided by two plus the distance from keel to tank top. In our case 6,93m/2 + 0,90m = 4,365m ≈ 4,37m. We will use this figure in our calculations. The same principle applies in calculating the longitudinal center of gravity.

Stability calculation load table

Departure

№	LOAD items		Load (t)	$KG_{(m)}$	Mkg (tm)	LCG(m)	Mxg (tm)	FSM, mt
1	**Light vessel**		**818,6**	**4,17**	**3413,7**	**34,64**	**28357,3**	
2	**Grainbulk**		**21,2**	**4,40**	**93,3**	**13,03**	**276,2**	
3	**Crew & provision**		**2,0**	**5,00**	**10,0**	**9,00**	**18,0**	
4	Forepeak		0,0	3,01	0,0	74,22	0,0	0,0
6	Ballast tank,	1 DB PS	89,5	0,46	41,2	60,09	5379,9	0,0
7	Ballast tank,	1 DB SS	89,5	0,46	40,9	60,09	5379,9	0,0
8	Ballast tank,	2 DB PS	56,3	0,45	25,5	40,50	2279,3	0,0
9	Ballast tank,	2 DB SS	56,3	0,45	25,5	40,50	2279,3	0,0
12	Ballast tank,	3 DB PS	57,8	0,47	27,2	21,41	1238,1	0,0
13	Ballast tank,	3 DB SS	57,8	0,47	27,2	21,41	1238,1	0,0
14	Ballast tank,	1ST PS	0,0	3,32	0,0	54,53	0,0	0,0
15	Ballast tank,	1ST SS	0,0	3,32	0,0	54,53	0,0	0,0
16	Ballast tank,	2ST PS	1,0	3,30	3,2	26,31	25,1	2,9
17	Ballast tank,	2ST SS	1,0	3,30	3,2	26,31	25,1	2,9
18	Afterpeak		0,0	3,85	0,0	1,27	0,0	0,0
19	Fuel tank DB 1C		0,9	0,45	0,4	43,75	37,2	96,4
20	Fuel tank DB 2C		6,0	0,45	2,7	28,15	167,5	96,4
21	Bow truster FO tank		0,9	6,91	5,9	70,70	60,1	0,3
22	Daily service tank		5,1	3,43	17,4	9,91	50,4	0,5
23	Settling tank		2,3	3,38	7,8	11,71	26,9	0,5
24	Fresh water tank PS		10,0	3,65	36,5	6,34	63,4	4,1
25	Fresh water tank SS		10,0	3,65	36,5	6,34	63,4	4,1
26	Dirty oil tank		0,2	1,82	0,3	10,02	1,8	1,6
27	Lub.oil tank		0,9	1,64	1,5	11,78	10,6	2,6
29	Dirty water tank		1,0	0,49	0,5	11,45	11,6	6,0
31	Sewagetank №56 PS		1,0	1,82	1,8	10,02	10,0	1,6
32	Constant		25,6	1,00	25,6	40,00	1022,4	
33	**Cargo in hold**		**1421,0**	**4,37**	**6176,5**	**42,22**	**59996,3**	
34	**Cargo on deck 1,5 stack**		**295,6**	**8,67**	**2562,9**	**38,48**	**11374,8**	
	Total weight		**3031,3**	**4,22**	12587	39,39	119392,8	219,9
	Non cargo stores, t		474,9	**KG**	**Mkg**	**Xg**	**Mxg**	**FSM**
	Total cargo, t		1716,6					
	Total deadweight, t		2191,5					
	Displacement, t		3031,3					
	Corrected displacement, t		3107,1					

Figure A-7. Table of loads and centers of gravity for stability calculations. (Björk, 2021).

The idea is to get a weight total, which is displacement, and a corresponding longitudinal and vertical center of gravity. In other words, to determine the center of mass for the ship as a whole. We need to calculate the vertical and longitudinal moments first. This is done by simply multiplying the weight with the center of gravity. So, for example, the cargo in hold has a vertical moment of 1421t * 4,37m = 6176,5mt and a longitudinal moment of 1421t * 42,22m = 59996,3mt. When we have calculated the vertical and longitudinal moments for each item in the table, we sum all the longitudinal moments as a total longitudinal moment and do the same for the vertical moments. In Figure A-7 this is already done. Because we know the displacement of the vessel, we can now work the same idea backwards. By dividing the total longitudinal moment with our displacement, we get the LCG for the ship as a whole. Divide the total vertical moment with our displacement and we get the KG for the ship as a whole. In our program this KG figure is already corrected for free surface moments, but I will explain the correction briefly.

In Figure A-7 you can also see a column labelled FSM. This stands for free surface moments and is caused by the contents of partially filled tanks shifting when the vessel is heeling. If we assume that the vertical centre of gravity is along a vessel's vertical centreline and the vessel has only completely full or empty tanks, the centre of gravity stays along the centreline when the vessel is heeling. The effect of FSM is that the partially filled tank content shift the centre of gravity horizontally to the side from the vessel's vertical centreline as illustrated in Figure A-8. If we draw and imaginary line vertically from this new centre of gravity, we will end up crossing the vessel's centreline at some point. This point is called a virtual centre of gravity (VVCG) and it is located higher than the actual centre of gravity, KG. The rise in height reduces the vessel's hydrostatic stability.

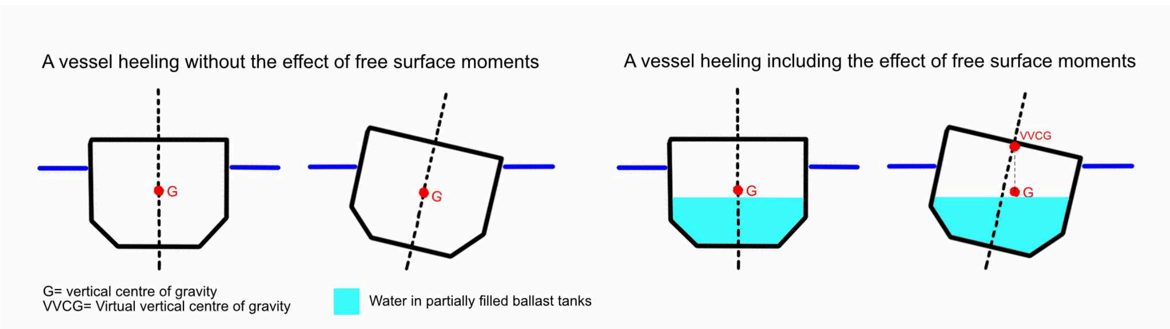


Figure A-8. The shifting of the centre of gravity due to the content of partially filled tanks. (Björk, 2021).

The amount of FSM depends on tank dimensions, the level to which it is filled and heeling condition. Modern stability programs can quickly calculate the effect for each heeling condition. To simplify the process, we often use the sum of maximum free surface moments for calculating a worst-case stability scenario to keep us on the safe side. In the simplified calculation we divide the sum of maximum FSMs with the actual displacement of the vessel and the result is the difference between vertical center of gravity and virtual vertical center of gravity. When we sum these, we will get a corrected vertical center of gravity.

If we take the information from Figure A-7 we can calculate the corrected vertical center of gravity for our vessel:

$$\frac{Sum\ of\ maximum\ Free\ Surface\ Moments}{Actual\ displacement\ of\ vessel} = Difference\ between\ the\ KG\ and\ VVCG$$

$$\frac{219{,}9\ mt/m}{3107{,}1\ mt} \approx 0{,}07\ m$$

The uncorrected KG of our vessel is 4,15m and if we add the difference obtained in the previous calculation, we get 4,15m + 0,07m = 4,22m. When we compare it to the corrected KG in Figure A-7 we can see that the result is the same.

Metacentre is a term that often comes up in stability theory as a lot of it revolves around the distances from somewhere to it. It bears a similarity to the VVCG in a sense that its place is defined by an imaginary vertical line. When a vessel is heeling, its centre for buoyancy shifts horizontally. If you draw an imaginary vertical line from this new centre of buoyancy to the vessel's centreline, you will find the metacentre at the intersection of the two lines as best illustrated in Figure A-9.

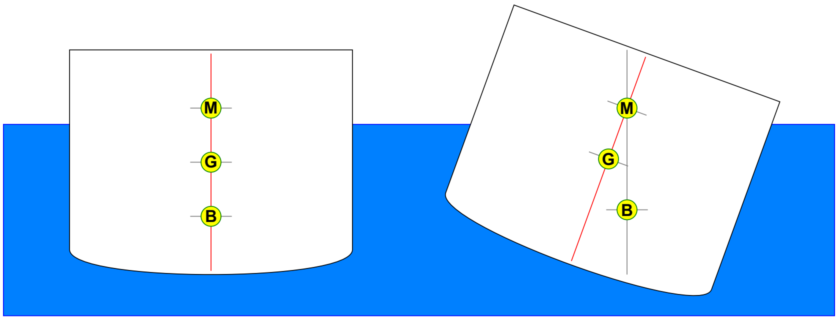
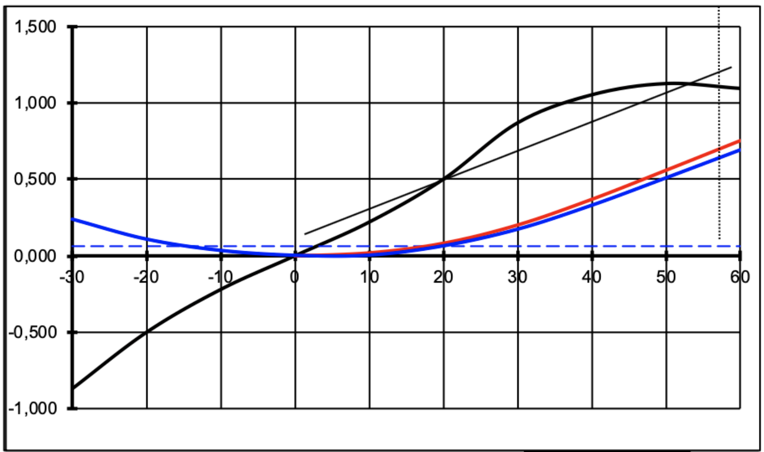


Figure A-9. The location of the metacentre is at the intersection of the vessel's centreline and an imaginary vertical line drawn from the centre of buoyancy when the ship is heeling. (Wikimedia Commons, 2011).

The metacentre acts as basis for the final stability calculations. What we are interested in the most is the distance between centre of gravity and the metacentre, or GM, as commonly labelled. We can calculate this by reducing the distance between centre of gravity and keel (KG) from the distance between the metacentre and keel (KM). The location of the metacentre depends on the vessel's displacement and the KM value can be found from the hydrostatic tables in the vessel's stability booklet. In our case the KM is 4,77 meters and, as per earlier calculations, our corrected KG is 4,22. If we reduce the KG from KM, we end up with 4,77m – 4,22m = 0,55m. This means that our distance between the metacentre and our vertical centre of gravity, or GM, is 0,55 meters.

GM represents the vessel's initial stability and on top of that we need to check that rest of the stability criteria is met. The stability criteria that are applied today is given in the 2008 IS Code by IMO and it states the minimum GM, righting lever at specific heeling conditions and relations between areas of the righting level curve. Righting lever is the moment that wants to straighten the vessel when heeling. To simplify, higher righting lever means that the ship has a higher tendency to return in an upright position.



GM=	0,55	m	> 0,15m
A30=	0,202	m*rad	> 0,055m*rad
A40=	0,369	m*rad	> 0,090m*rad
A40-A30=	0,168	m*rad	> 0,030m*rad
B=	0,510	m*rad	
A=	0,008	m*rad	
B/A=	67,271		> 1 (weather crit.)
GZ30=	0,870	m	> 0,2m
GZmax=	41	grad	> 25grad
Ka=	4,9		> 1 OK!

All calculations according to Information of stabilyty of m/v "EXAMPLE"

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Figure A-10. The IMO stability criteria and GZ curves from our stability calculations. (Björk, 2021).

Figure A-10 is an outtake from our vessel's stability calculations that shows the criteria and the righting level curves. The x-axis represents the angle of heel in degrees and the y-axis the length of the righting lever, which is called GZ. As you can see from the figure, the minimum GM allowed for cargo ships is 0,15 meters. Furthermore, the criteria states that at a heeling angle of 30 degrees, the GZ should not me less than 0,20 meters and the maximum GZ should occur at an angle less than 25 degrees. The areas below the GZ curve should not be less than 0,055 meters*radian up to 30 degrees, not less than 0,090 meters*radian up to 40 degrees, and the difference between the two must be more than 0,030 meters*radian. As we can see in Figure A-10, all the intact stability criteria are met and we can state that concerning stability, the vessel is seaworthy.

Appendix B – Departure Checklist

B6 PREPARATIONS FOR SEA

Passage Plan	Tick
Berth to berth passage plan for the intended passage prepared and available on the bridge with the route plotted on up to date and appropriate scale charts (official paper or electronic)	
Passage plan checked and approved by the Master	
Passage plan briefed to the Bridge Team	
Route displayed on ECDIS and/or other electronic navigation aids, as appropriate	
Up to date charts and nautical publications available	
Latest Notices to Mariners (week number):	
Equipment Checks (Tested and Ready for Use)	
AIS (voyage data updated and correct)	
Anchors, cables and winches	
Ancillary bridge equipment (e.g. binoculars)	
BNWAS	
Clocks synchronised with engine room	
Controllable pitch propeller controls and indicators	
Course and engine movement recorder/bridge movement book	
Deck power	
ECDIS and/or other electronic navigation aids	
Echo sounder	
Electronic position fixing systems	
Emergency engine stops	
Engine(s)/propulsion (ahead and astern)	
GMDSS communications and GMDSS log	
Gyro/magnetic compass and repeaters, including repeater in steering gear area	
Internal communications (particularly bridge to engine room/bridge to mooring stations)	
LRIT	
Navigation lights, shapes and sound signals	
Radar(s) and ARPA	
RPM and ROT indicators	
Signalling equipment including flags, search lights and signal lamps	
Speed and distance log	
Stabilisers	
Steering gear (Checklist B1)	
Thrusters	
VDR/S-VDR	
Port and Pilotage	
Master/Pilot information exchange checklist completed (Checklist A1)	
Pilot Card prepared (Checklist A2)	
Pilot boarding time confirmed	
Pilot boarding arrangements ready for disembarkation of the Pilot (Checklist A4)	

Port and VTS channels monitored	
Port, VTS and Pilot advised of any special requirements	
Preparations for pilotage complete (Checklist B8)	
Securing for Sea	
Cargo and cargo handling equipment secure	
Cargo/passenger details available	
Hull openings secure and watertight	
Stability and draught information available	
Watertight doors closed	
Before Sailing	
All crew on board	
Anchors cleared away	
Bridge Team fit for duty	
Engine room ready	
Mooring stations manned and ready	
MSI checked and communicated to Bridge Team	
Pressure on fire main	
Stowaway/security search completed	
Other	

Time and Date:..

OOW Signature:..

NB: The above points are recommendations only. It is essential that the checklist is amended to reflect the appropriate operating manuals and Company procedures.

An example of a departure checklist (Bridge Procedures Guide, 2015).