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Kaj Riska

THE INFLUENCE OF SHIP CHARACTERISTICS ON ICEBREAKER DEMAND

Finnish Transport Safety Agency

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FOREWORD

In its report no 72, the Winter Navigation Research Board presents the outcome of the project on the influence of ship characteristics on icebreaker demand. The winter navigation to and from Finnish ports is based on icebreaker escort offered to all ships fulfilling the navigation restrictions set by the maritime authorities. The navigation restrictions give the ice class required and also the minimum deadweight allowed. The ice class requirements contain a requirement for a minimum ice-going performance, which is different for each ice class. The basis of the ice-going performance requirement (stated as a minimum power requirement) is that merchant ships should be able to follow icebreakers with an adequate speed and also to proceed independently in lighter ice conditions, prevailing usually close to the ice edge. The minimum deadweight requirement is set in order to make the traffic i.e. the winter navigation system as cost effective as possible.

The aim of this study is to investigate the need for ice breaking services, if a new trade segment is introduced. A concrete example of such a new demand for ice breaking services is presented assuming that ore transport from the mines in the Kolari region in the northern Finland starts through the hub in Kemi (port of Ajos). This sea transport demand is used as an example of the icebreaker demand calculations, but the basic principles of the study can be applied to any new transport demand. The result of the study is the number of icebreakers needed to support the assumed transportation demand.

The Winter Navigation Research Board warmly thanks Professor Kaj Riska for this report.

Helsinki and Norrköping

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THE INFLUENCE OF SHIP CHARACTERISTICS ON THE ICEBREAKER DEMAND

The bulk carrier trade to northern Finland used as an example

Contract: June 7, 2010 Finnish Transport Safety Agency and Swedish Maritime Administration

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1. INTRODUCTION

The winter navigation to and from Finnish ports is based on icebreaker escort offered to all ships fulfilling the navigation restrictions set by the maritime authorities. The navigation restrictions give the ice class required and also the minimum deadweight allowed. The ice class requirements contain a requirement for a minimum ice performance which is different for each ice class. The basis of the ice performance requirement (stated as a minimum power requirement) is that merchant ships should be able to follow icebreakers with an adequate speed and also to proceed independently in lighter ice conditions, prevailing usually close to the ice edge. The minimum deadweight requirement is set in order to make the traffic i.e. the winter navigation system as cost effective as possible. These measures – requiring some ice performance, ice class and certain minimum amount of cargo – aim to make the shipping as fluent without undue stoppages and as economic as possible by limiting the number of icebreakers required.

The balance between the icebreaker fleet, number of ship visits during wintertime (on average about 8000 ship visits to Finnish ports and about 3500 to Swedish ports where traffic restrictions have been in place in winter 2009-10) and the waiting time for an icebreaker has been reached. The criteria for a well functioning winter navigation system has been set so that 90 – 95 % of the ships should not need to wait for an icebreaker; and for those ships that must wait for an icebreaker, the average waiting time should be less than 3.5 h. In the winter 2009-10 the average waiting time was 4.9 hours to Finnish ports while the average from last four years is 3.1 h. At the same time 88.4 % of the ships did not have to wait for an icebreaker. These numbers show that the winter navigation system works in general well. Not all of these ships visiting Finland in wintertime need icebreaker escort, for example during the winter 2008-9 2432 ships (about 16 % of all ships) required escort – this winter was slightly milder than a long term average.

The length of waiting time is very sensitive to changes in the transport patterns. Introduction of new ship routes that increase the number of ships in traffic and number of ports-of-call changes the demand on icebreakers. Changing the ice capability of the merchant fleet also has a direct impact on the need of icebreakers. The ice capability of the merchant fleet is influenced by the technical ice capability of the ships but as important is the experience and competence of the crews. If the number of icebreakers does is not adjusted to changing traffic, the waiting times will change.

The aim of this study is to investigate the need for ice breaking services if a new trade segment is introduced. A concrete example of such a new demand for ice breaking services is presented if the ore transport from the mines in the Kolari region starts through the hub in Kemi (port of Ajos). This transport need is used as an example of the icebreaker need calculations but the basic principles of the study can be applied to any new transport. The result of the study is the number of icebreakers needed to support the studied transportation. The determination of this new need for icebreakers makes it possible to assess the impact of the new transport route on the present icebreaker services. The merchant ship fleet for this trade is not known so first the ship design for this trade is investigated. Once the ships are sketched, the icebreaker need in an average winter is determined. The icebreaker need is influenced much by the ice performance of the assisted ships – thus the demands to be placed on the merchant ships are also reflected upon.

This report is based on the work carried out to prepare the presentation Riska: Bulk Carriers for the Northern Baltic; Design Considerations, presented at Ice Day 2010 in Tornio, Finland. Changes to the ship design and to the data about the icebreaker assistance have, however, been made after the presentation and consequently some items in the icebreaker escort estimates have been changed.

2. TRANSPORT NEED

As the method developed to estimate the icebreaker need is applied to the concrete case of iron ore transport out from Kemi port, this project is presented shortly. The ore comes from the iron ore deposit in the Kaunisvaara-Kolari area, shown in Fig. 1. This export creates a transport need the impact of which on required icebreaking services is investigated in this study. The ore deposit is on Finnish and Swedish territory about 180 km from the northern rim of the Gulf of Bothnia. The closest ports to the ore deposit are in Kemi – Kalix area in Finland and Sweden as well as in Narvik, Norway. The export through ports in the Gulf of Bothnia is favoured by the existing rail link that must, however, be updated for this trade (MINTC 2009), Also the ports and fairways to ports need construction work before being suitable for this trade.

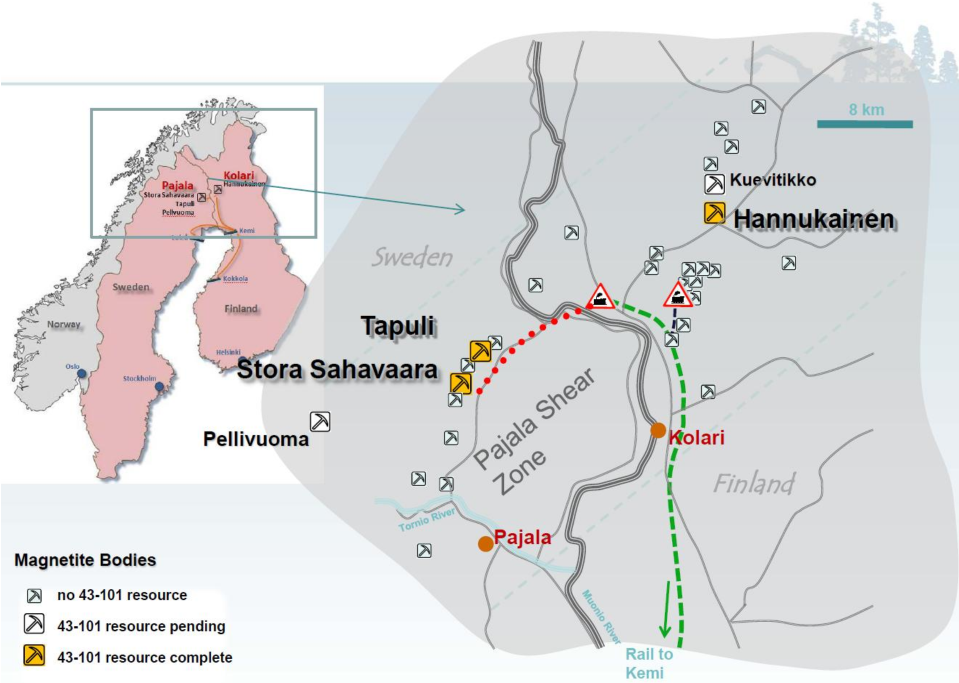

Fig. 1. Location of the ore deposit (Nilsson 2009).

The amount of ore to be transported has not been settled, yet. The build-up phase involves 0.5 million tons in 2012 and 3.5 million tons of ore in 2013 (Nilsson 2009). The final planned amount of ore to be transported annually varies between 5 and 7.5 million tons per year (Mtpa). The transport plans are not finalized, yet, and several options for transport are open as the press release from Northland Resources Inc. cited below states (www.northlandresourcesinc.com 23.8.2010):

(quote) *Luxembourg, July 21, 2010: Northland Resources S.A. ("Northland" or "the Company") is studying the possibility of exporting its iron ore concentrate from the existing Scandinavian port of Narvik, which already handles Cape-Sized dry bulk cargo vessels from its deep water port. Northland also continues to evaluate using the port at Kemi, Finland, and the two port studies will be developed in tandem. The Company is in advanced discussions with potential off-take parties in the Middle East and the Far East for a majority of its 5 Mtpa future production from the Kaunisvaara Iron Ore Project. "The interest we have received from potential overseas customers makes it necessary to investigate an additional port alternative in parallel to Kemi," stated Karl-Axel Waplan, President and CEO of Northland.*

Exporting from a deep water port would provide a great advantage in maximizing the received Free On Board price ("FOB") for overseas demand. The Port of Narvik in Norway is presently *used for the shipment of LKAB's (Sweden) iron products. The Port can handle up to 250-300,000 dwt vessels and a substantial amount of the required terminal infrastructure is already in place. This should mean that the required terminal investments in Narvik could be substantially lower than at the Port of Kemi. In addition, the use of the Port of Narvik, compared to the Port of Kemi, should remove transshipment expenses, as the existing Kemi alternative requires the transfer of iron ore concentrate from Handy-Max to Cape-Size vessels. The Port of Narvik will also provide year-round, ice-free export of iron ore concentrate.*

As scheduled, the Management team presented the Board of Directors the draft Definitive Feasibility Study (DFS) at the beginning of July. The Board reviewed the results of the study and it was decided to review the possibility of using a deep sea port before finalizing the DFS. Northland expects the studies on the alternative port solutions to be finalized during late summer this year.

To reach the Port of Narvik, the Kaunisvaara concentrate would be trucked 120 km to an existing heavy-haul railway between Sweden and Norway. The existing roads and rail can handle Kaunisvaara's planned production volume. Initial investigations suggest that the added cost of using trucks is more than offset by reduced overall shipping costs to market and the higher received FOB price for deliveries to the Middle East and the Far East markets.

Despite one of the partners in the Kemi Bulk Terminal ("KBT") consortium, Euroports Holdings S.à r.l., withdrawing from the joint-venture, Northland and Havator are continuing with discussions on a co-operation, both in respect of the Kemi option as well as the Narvik option. (end quote)

Just when the calculations for this study were finalized, Northland Resources published a news release (September 27, 2010) where the decision on the ore transport was stated:

(quote)*The current logistics option includes:*

- *Truck transportation from Kaunisvaara to Svappavaara for reloading to railway wagons*
- *Rail transportation from Svappavaara to Narvik on the railway track 'Malmbanan' -- currently used for iron ore transport by other operations in the region*
- *Use the Fagernes terminal in Narvik as a temporary solution (5-6 years) and the Company is working with the Municipality to find a long-term terminal solution* (end quote)

Notwithstanding the decisions in the development plans, the ore transport route through Kemi is used here as a concrete example of determining the icebreaker need – and balancing this need with demands on the merchant ships.

3. SHIP DESIGN

The study of the need for ice breaking services is not possible without some knowledge of the ships to be assisted. The aim now is to sketch two versions of the ore carriers; one in ice class IA with a conventional hull form and the other in ice class IA Super with an ice breaking hull form. A conventional hull form includes bulbous bow with relatively steep verticals. An ice breaking hull form includes a bow made for ice breaking – the stem angle must be less than, say, 45^o. The final fleet of ore carriers most probably will contain a mix of different ships, some more suitable for winter trade and others for the open water season. The reasons for selecting these ship types will be clearer when the design boundary conditions are analyzed below.

A comment on the selection of ship types in view of the development of so called double acting ships that have an ice breaking stern with azimuthing thrusters and an open water (bulbous) bow, Suojanen et al (2006), might be in place. The advantage of these ships is that they do not need an icebreaker escort even in heavy winters – but the price of the ships is quite prohibitive, about 13 – 22 % more expensive compared with a ship in ice class IA Super with an ice breaking bow. This cost increase is difficult to cover with any support mechanisms (see e.g. Riska 2008); thus the cost increase leads to increased required freight rate (RFR).

Draught and length

The present draught of the fairway to Kemi is 10.0 m (Fig. 2) which is not enough for larger ore carriers. Additionally to the draught, the fairway is designed to the ship main dimensions L_{OA} = 180 m and B = 27 m (fairway card at www.fma.fi). As the fairway is not large enough for the ore traffic, there is a plan to increase the present 10.0 m fairway draught to 12.0 m, see for example the home page of the Finnish Transport Agency www.fta.fi. The fairway design will include some ship length which has been stated to include a length (L_{OA}) 240 m. The similar 12.0 m fairway to Kristiinankaupunki used a maximum length of 210 m. The present safe clearance depth is 11.4 m in the harbor basin – this is just adequate for the draught of 10 m and maximum sea level variations as the minimum water has been 1.25 m below the MWL (see e.g. Ramboll 2009).

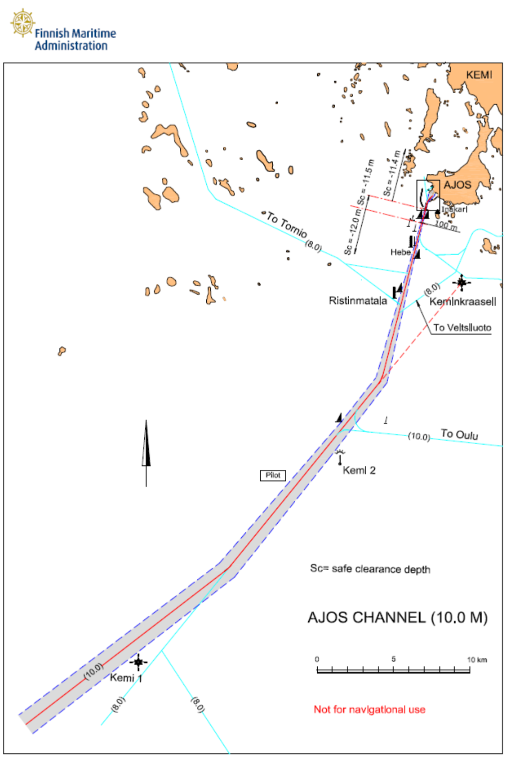

Fig. 2. Fairway leading to the Kemi port of Ajos (www.fma.fi).

The harbour basin in port of Ajos is quite restricted (see Fig. 3) and thus the ships must turn outside the harbour basin. This means that ships must go in (or out) astern. At present the plan is to change the quay where the oil pier and Sampo quay are located to the ore quay. The ability to go astern in ice must be taken into account in designing the stern and rudder arrangement of the ships; but this is a detail that does not change the overall design.

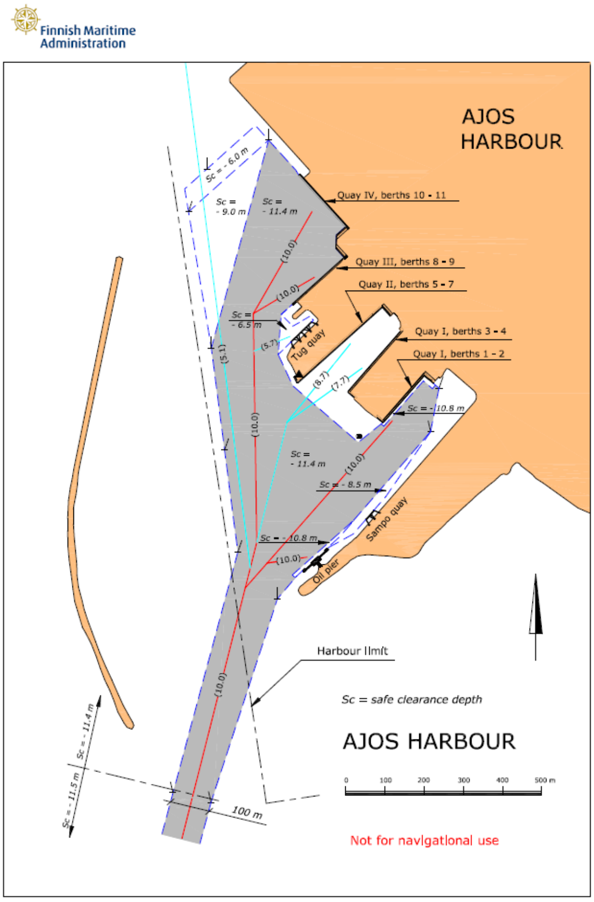

Fig. 3. The present Ajos port (www.fta.fi).

Beam

The restriction to ship beam comes mainly from the operation in ice. Larger beam decreases the ice performance by increasing the ice resistance much. Also the escort speeds will be low if the ship beam is wider than that of the escorting icebreaker because then also the escorted ship must break some ice. A rough estimate of the increased ice resistance can be obtained from model tests carried out for an Arctic transport system (Riska et al. 2006); if the escorted ship is 25 % wider than the icebreaker (see the photo in Fig. 4), its resistance increases by a factor of about 2.3 from the resistance in the broken channel – this means at least a 2 knots decrease in the escort speed i.e. in the speed that the escorted ship can follow an icebreaker. An alternative to wide icebreaker beam is to escort ships with two icebreakers as shown in Fig. 4. This is not an economic alternative and is not considered here.

The present beams at the waterline of Finnish and Swedish icebreakers that are used in the Gulf of Bothnia are as follows:

IB Urho, Sisu, Atle, Frej and Ymer	22.9 m
IB Otso, Kontio	23.6 m
MSV Fennica, Nordica	25.5 m

IB Oden	29.4 m

Of these icebreakers, IB Oden is often chartered to some other work.

Based on the icebreaker beams, the maximum beam of the ore carriers is restricted to 28.0 m which is about 10 % larger than the largest present icebreaker beam.

Fig. 4. Escort of a wide tanker with two icebreakers (photo: Atso Uusiaho).

Ice class

An adequate ice class to the prevailing ice conditions and available icebreaker escort ensures safe and continuous passage. Finnish and Swedish maritime authorities give the required ice class in the traffic restrictions – the highest ice class required (in order to get icebreaker escort) of ships bound to the ports in the northern Gulf of Bothnia is IA. The traffic restrictions giving the ice class required and also the minimum deadweight are shown for example in the ice charts issued by the Finnish Ice Service, see Fig. 5. It should be noted that fulfilling the Finnish-Swedish ice class requirements does not necessarily lead to a successful ship in ice. Thus the Head of Icebreaking Division in Finland or Sweden can deny or postpone assistance to a ship, although the ship formally meets all requirements. This action is usually based on reports from icebreaker masters stating that the ship is not suitable for winter navigation and causes thus unacceptable delays for other ships.

The highest ice class requirements to the port of Kemi are commonly ice class IA. Thus only ships in ice classes IA and IA Super will be considered here.

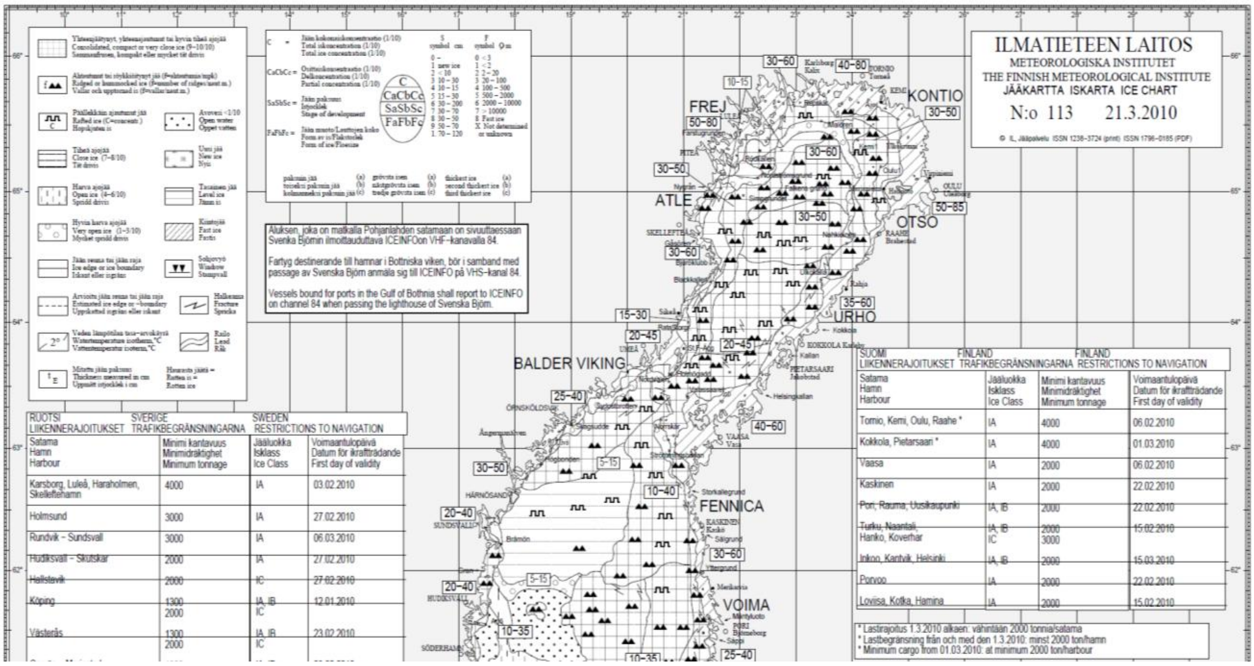

Fig. 5. The ice conditions in the end of March and the traffic restrictions (www.fmi.fi).

Calculated main dimensions

As stated, two different ships are designed. One is a conventional bulk carrier of a deadweight about 40 000 dwt with a bulbous bow and an ice class IA and the other an ice-going ship of somewhat smaller deadweight, an ice breaking bow and an ice class of IA Super. The basis for the calculation of the main dimensions is: (a) the statistics from built bulk carriers giving the dimensions versus the deadweight, (b) selection of the block coefficient for the IA and IA Super ships and (c) the weight balance. Additionally the effect of ice class has been taken into account in reducing the deadweight of ice classed ships versus the corresponding open water ships. The results of the calculation of main dimensions are given in Figs. 6 and 7 for the conventional and ice going bulk carriers. The steps in the dimensions curves reflect the decision to first increase (versus deadweight) the draught and then the beam to the limits before starting to increase the length additionally. It should be remembered that these main dimensions are derived in order to be able to assess the need for icebreakers – thus these are very preliminary.

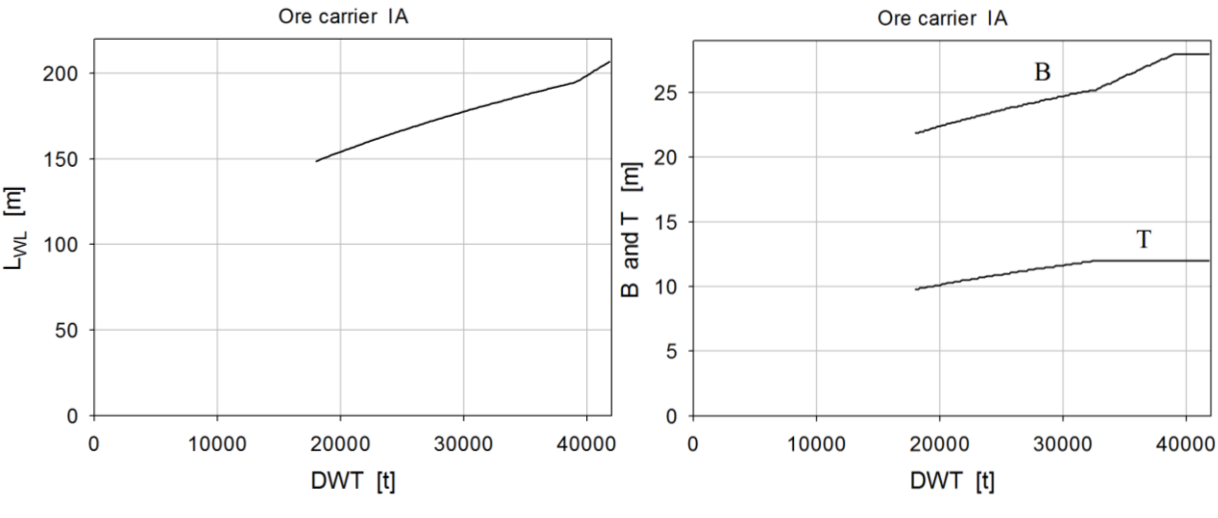

Fig. 6. The main dimensions of the conventional ore carrier.

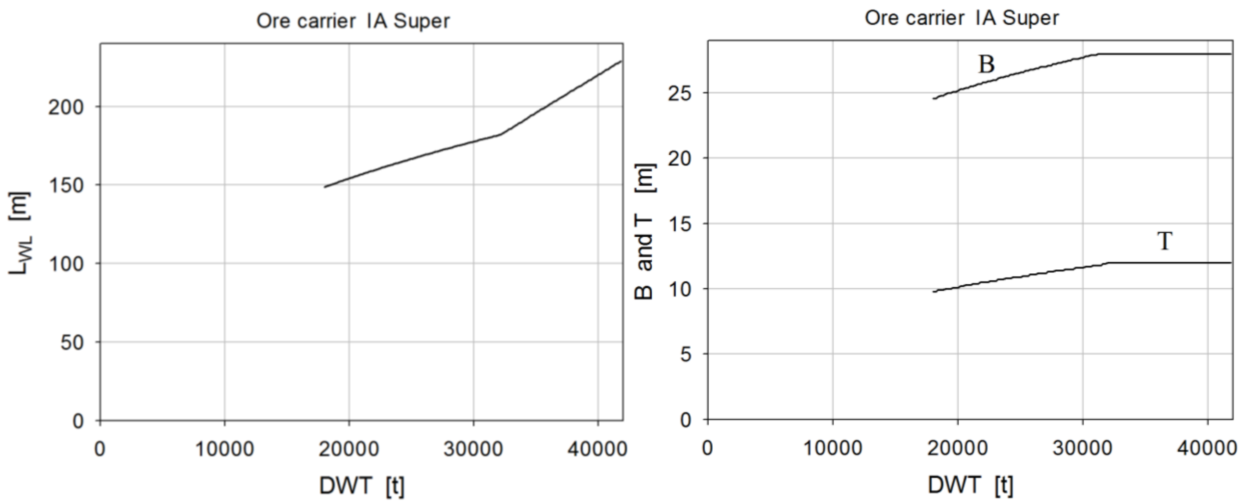

Fig. 7. The main dimensions of the ice going ore carrier.

Power selection

The required minimum propulsion power is estimated for open water performance and according to the ice class. The open water power requirement is based on 14 – 15 knots open water speed and is done roughly estimating the resistance based on the block coefficient and main dimensions and based additionally on an estimated propeller diameter. The Finnish-Swedish Ice Class Rules require a minimum performance in ice for each ice class. The requirement is stated as a performance requirement but an equation for the minimum power requirement is given as well in the Rules. The required open water power and the minimum power in ice are given in Fig. 8. It should be emphasized that these are the minimum powers and the question of power will be investigated in more detail when looking at the demands on the icebreaker fleet.

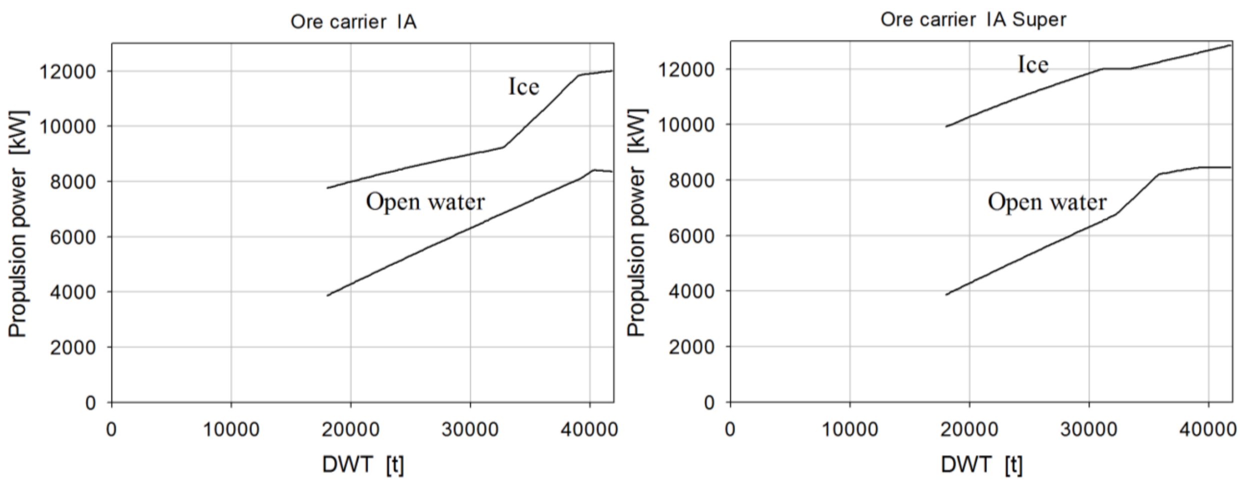

Fig. 8. The minimum required power to maintain about 14 knots open water speed and to fulfil the ice class requirement.

4. ICEBREAKER SUPPORT

The needed icebreaker support is estimated based on the ice conditions in an average winter. Once the data from an average winter is collected, the ship transit times through ice are calculated. The transit through ice is either independent or, when the ship transit speed gets low, escorted. The average speed proceeding independently or escorted depends on the ice conditions – a low speed achieved is the main criterion for needing icebreaker support.

Ice data from an average winter

The ship route is divided into segments on which the equivalent ice thickness (h, given in cm) and segment length (L, given in nautical miles, nm) is determined. The equivalent ice thickness gives a measure of all ice, both undeformed and deformed ice, along the segment; this equivalent thickness is used in estimating the ship speed. An example of the division into segments is given in Fig. 9. All the ice data is given in Table 1.

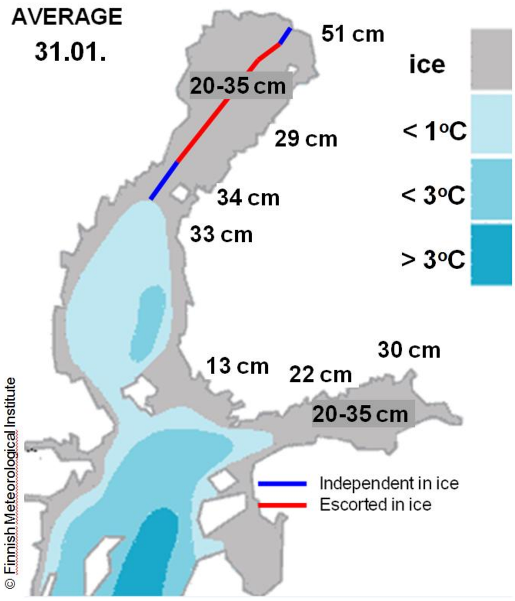

Fig. 9. The average ice extent and thickness in the end of January and the route segments selected (chart from Finnish Meteorological Institute). The colour code for temperatures refers to sea surface temperature.

Table 1. Ice data used in the study

Date	Segment 1		Segment 2		Segment 3	
	L [nm]	h [cm]	L [nm]	h [cm]	L [nm]	h [cm]
15.12.	15	12				
1.1.	30	19				
15.1.	35	25	20	12		
1.2.	40	34	60	18		
15.2.	55	41	90	24		
1.3.	55	47	140	30		
15.3.	60	53	140	36	30	12
1.4.	60	60	140	48	30	18
15.4.	40	60	150	54	30	18
1.5.	0	0				

The ice data is plotted in Fig. 10 where the equivalent ice thickness on the first segment from Kemi is given as well as the total length of the segments. It is clear that there is quite large scatter in ice conditions in real winters. This should be taken into account in making a more thorough study. Here only the average winter is used to represent the different winters.

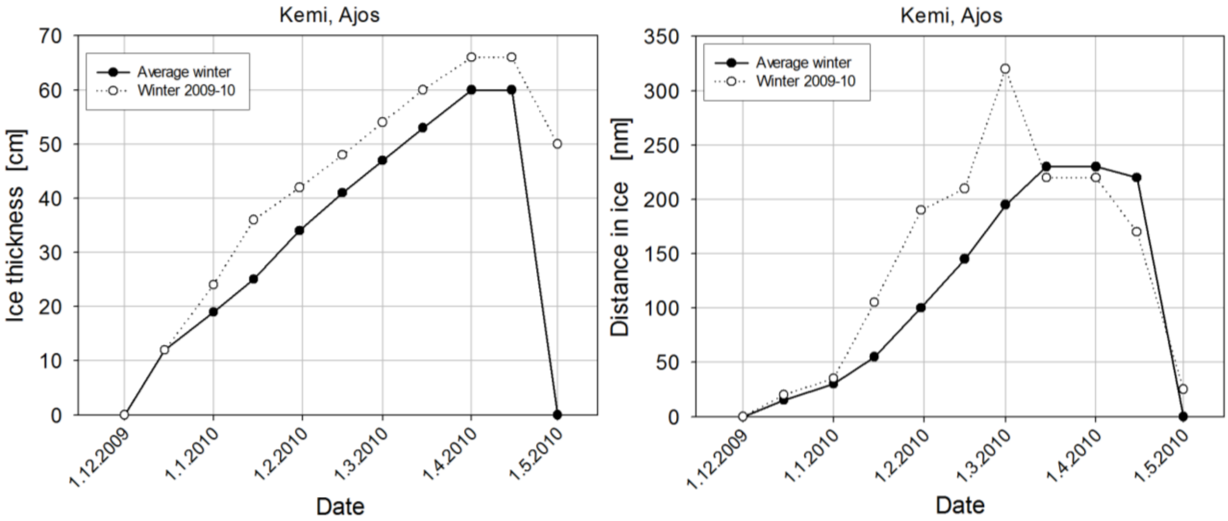

Fig. 10. The equivalent ice thickness in the first segment close to Kemi and the whole distance in ice from Kemi. The data from an average winter is compared with data from the recent winter 2009-10.

Some insight of the possible variation in ice thickness is obtained if the average and minimum/maximum ice thickness is calculated based on the air temperatures in Kemi. These temperatures are shown in Fig. 11. The calculated ice thickness based on the average temperature is 80 cm and using the minimum and maximum temperatures thicknesses of 50 cm and 100 cm, respectively, are obtained. These figures represent the ice thicknesses in the shorefast ice close to the port where ice has grown without any ice motion throughout the winter.

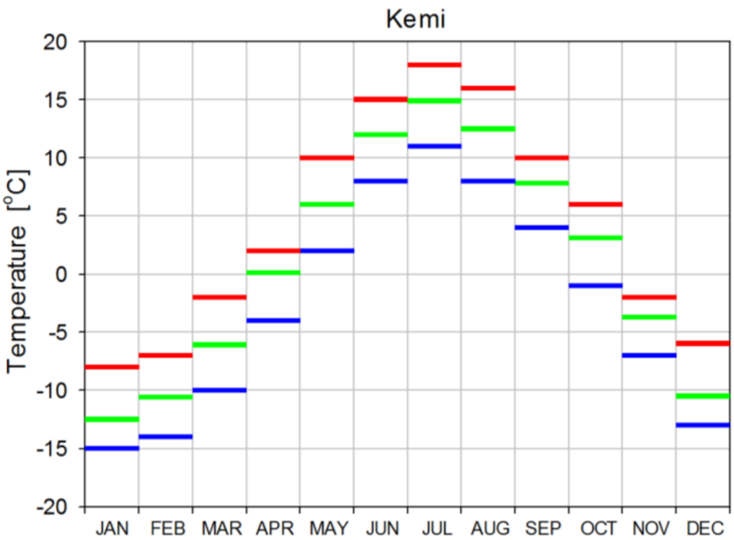

Fig. 11. The monthly average and average minimum/maximum temperatures in Kemi.

The ships studied

The icebreaker study is carried out by using two different ships as examples of the bulk carriers. The other ship is a conventional ore carrier with a bulbous bow having an ice class IA and the other is an ice going ship with an ice breaking bow and an ice class IA Super. The main dimensions of the ships are:

	Conventional, IA	Ice breaking, IA Super
Deadweight	40 000 dwt	22 000 dwt
L_{pp}	198.9 m	159.5 m
B	28.0 m	25.8 m
T	12.0 m	10.5 m
P_D	11.9 MW	10.6 MW

The power given is the minimum power for the ice class. This minimum power is used to carry out the icebreaker study but the power may be revised later based on the required rotation. The general views of the ships are given below in Fig 13.

The ice breaking capability is calculated for both ship versions. This capability is given by the ship speed reached in level ice of different thicknesses and also as the speed reached in old brash ice channels of different thicknesses. These h_i-v and H_M-v plots are given in Fig. 12. The difference in the ice performance of these ships is partly due to the difference in the beam and bow shape and partly due to the difference in power.

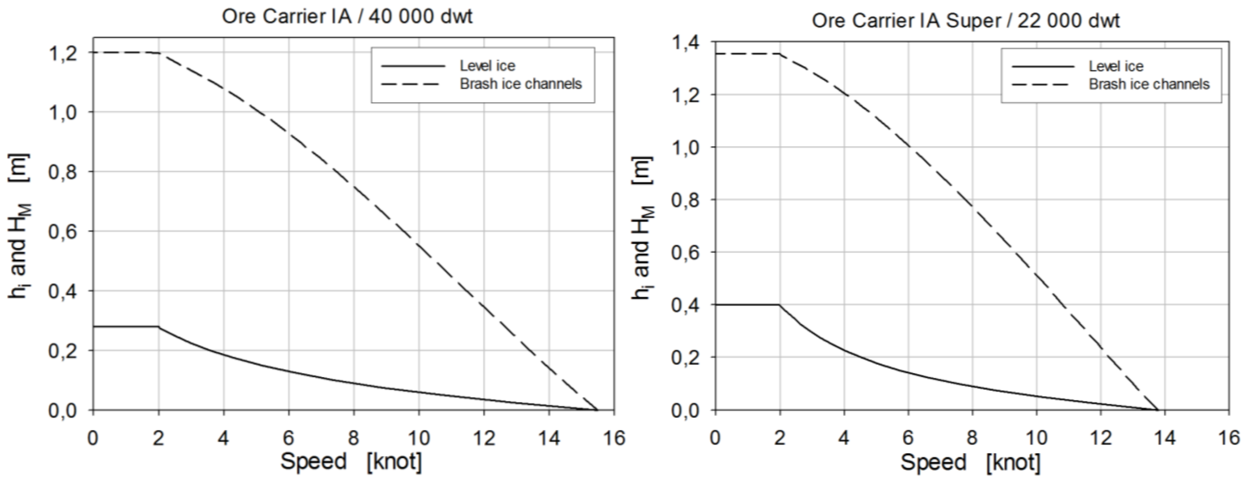

Fig. 12. The ice performance of the two ore carrier versions in level ice and in brash ice.

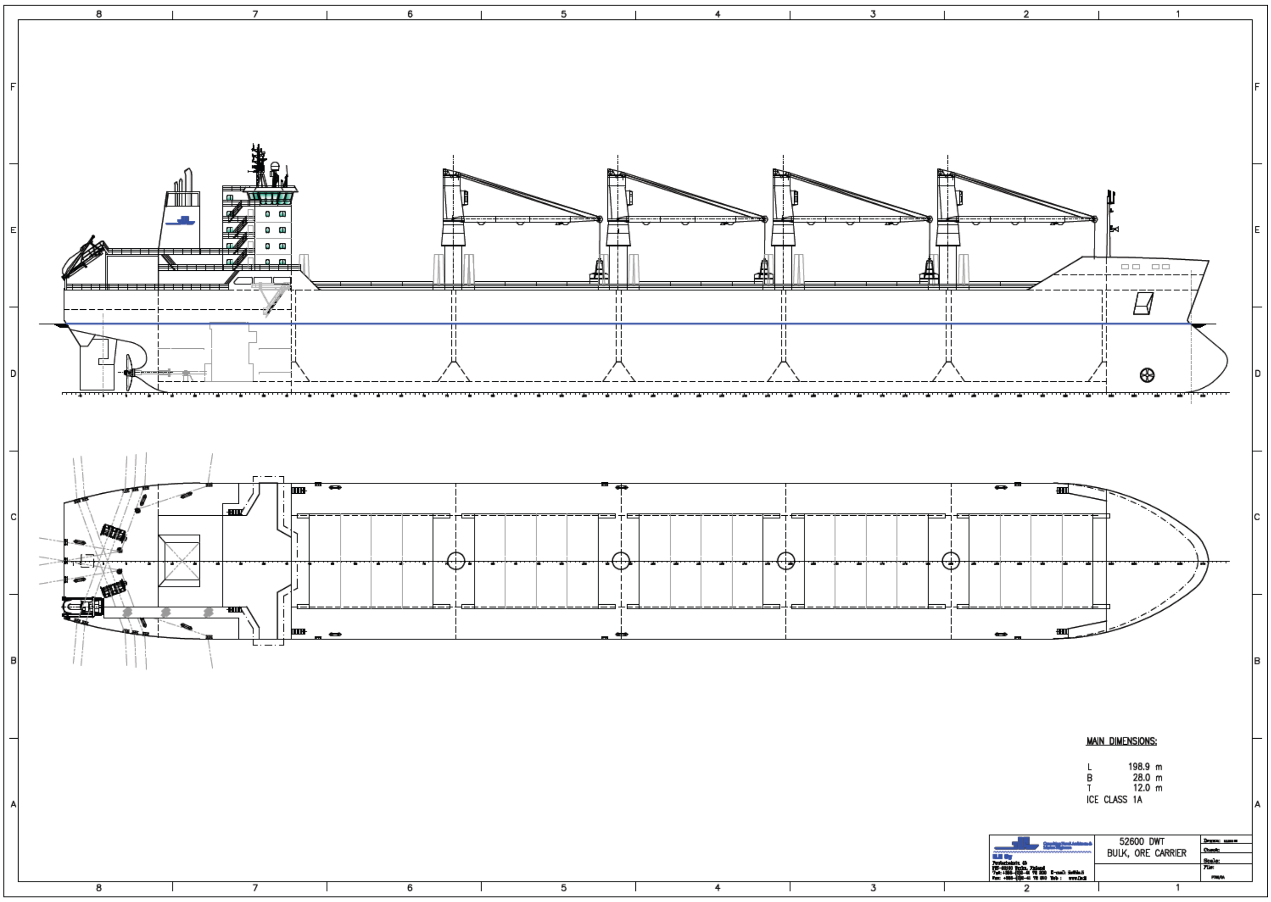

Fig. 13a. The conventional bulk carrier of ice class IA

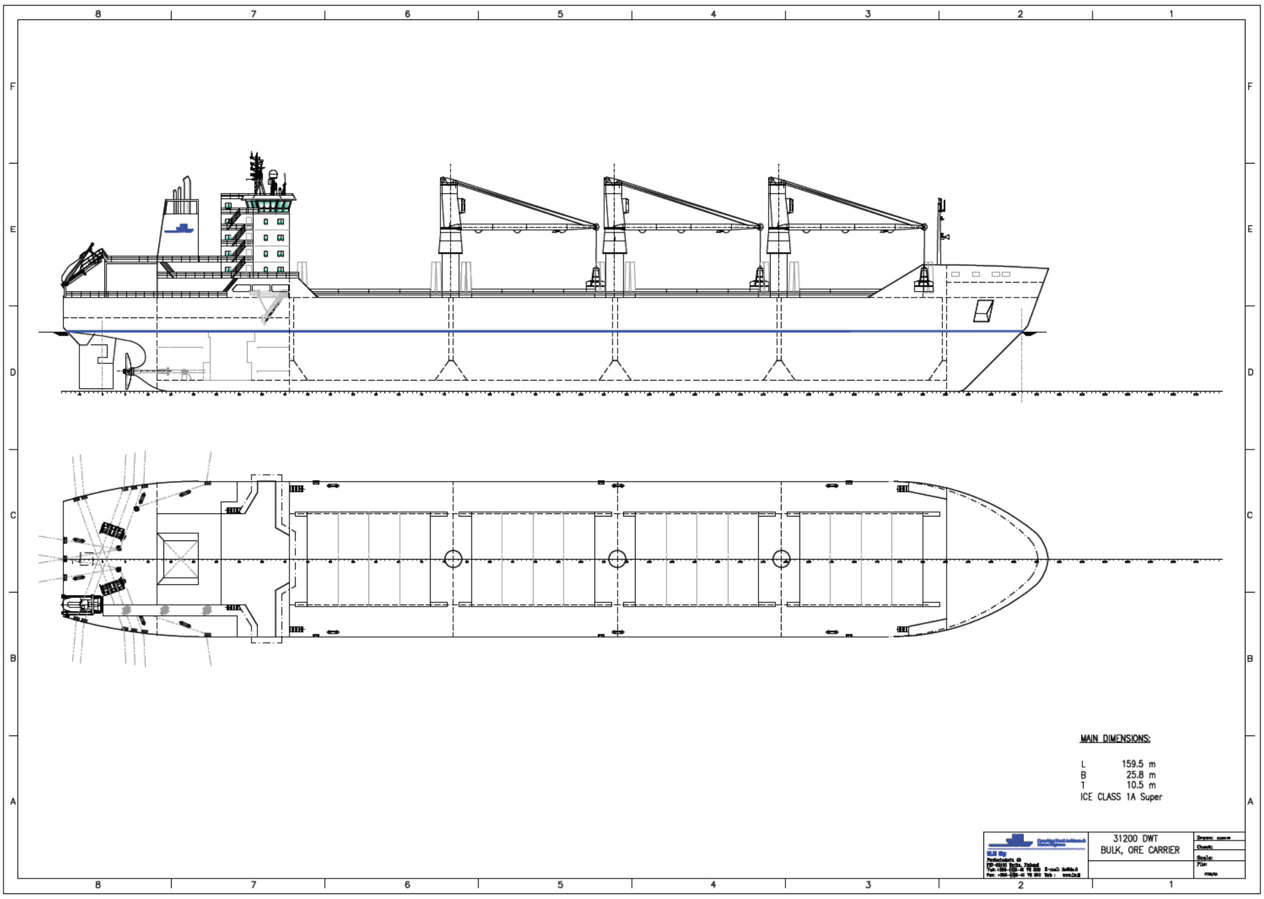

Fig. 13b. The ice breaking bulk carrier of ice class IA Super.

Icebreaker usage

One voyage of the ships is studied in half month intervals – the same intervals as the ice data is given. Some assumptions are made in deriving the transit times:

- The speed in ice is determined by using the equivalent ice thickness as the ice thickness in the *h*-*v* plots;
- The brash ice channel thickness at the centreline of the channel is assumed to be $H_M = 1.25 \cdot h_{eq}$;
- When the ship is proceeding escorted, the escort speed is assumed to be 10 knots for the IA Super ship and 8 knots for the IA ship;
- The limiting speed when a ship needs icebreaker escort is when its speed is below 6 knots;
- The average transit speed in open water is 12 knots.

The above assumptions are based on the data given by the icebreaker practices. The average escort speed in winter 2010 has been 9.4 knots and the towing speed 8 knots. The ship speed when the icebreaker starts to tow a ship is 6 knots. Larger ships cannot, however, be towed as the steering capability of the icebreaker would be very poor - thus the assistance of the bigger ships can rather be called a close escort, see the cover photo.

The data for ice conditions and the ship performance in ice can now be used to calculate the time lost in ice as compared with a port call during the open water season (assuming the same distance for both cases). If the average speed in an ice segment i of length L_i is v_i and the open water transit speed v_{ow} (assumed to be 12 knots) then the time lost due to ice in one port visit (i.e. round trip) is the total time of open water transit on all route segments subtracted from the ice transit time i.e.

$$T_L = 2 \cdot \sum_i L_i \left(\frac{1}{v_i} - \frac{1}{v_{ow}}\right),$$

where the factor of two comes from the assumption that the incoming and outgoing voyages are similar. Also the time under icebreaker escort during the round trip can be calculated similarly. These times are shown in Fig. 14. The calculation of transit times does not include the potential waiting times for an icebreaker.

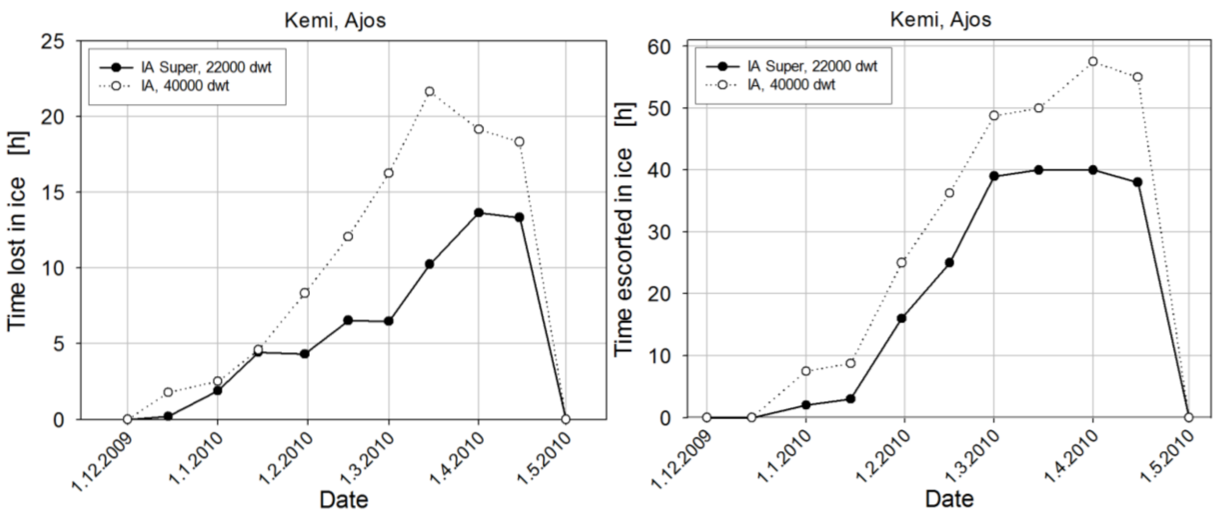

Fig. 14. The time lost due to ice versus the open water season and the time escorted during one round trip to Ajos.

These icebreaker times spent in escorting the ships enable the calculation how much icebreaker usage the transport requires. The transport cycle (ship rotation) is the main parameter here. Taking into account that not all deadweight is cargo, the following cycles of port visits can be calculated for both ships for different annual amounts of ore, see Table 2. Note that the time between visits is the inverse of the rotation.

Table 2. The ship cycle frequencies and lengths for different annual cargo amounts

Ship	22 000 dwt, IA Super		40 000 dwt, IA	
Annual amount	Rotation	Time between visits	Rotation	Time between visits
1 Mtpa	0.138 ships/day	7.23 d	0.072 ships/day	13.87 d
3 Mtpa	0.415 ships/day	2.41 d	0.216 ships/day	4.62 d
5 Mtpa	0.692 ships/day	1.45 d	0.361 ships/day	2.77 d

The ship rotation given in Table 2 and the amount of time that icebreaker escort is needed (Fig. 14) per a round trip makes it possible to estimate how much icebreaker assistance the trade requires. This is calculated as the ratio of icebreaker escort time needed per the rotation time (time between ship visits). This ratio can also be called icebreaker usage; if this ratio is one, one icebreaker is required full time to assist the ore trade and if the ratio is more than one, more than one icebreaker is required. These results of icebreaker usage are presented in Fig. 15. The icebreaker usages have been calculated without any waiting times for an icebreaker. If the target waiting times and amount of ships going through without any waiting, some 2 x 0.4 h waiting time should be added in the time spent in ice.

It is clear that the amount of exported ore (which sets the rotation) is the main parameter, together with the ship size. When looking at these results, it should be remembered that no waiting time for icebreakers is included and the ships' ice performance is based on fulfilling the minimum power requirement based on the ice class selected. If the export is 5 Mtpa, it can be seen that one icebreaker is needed full time.

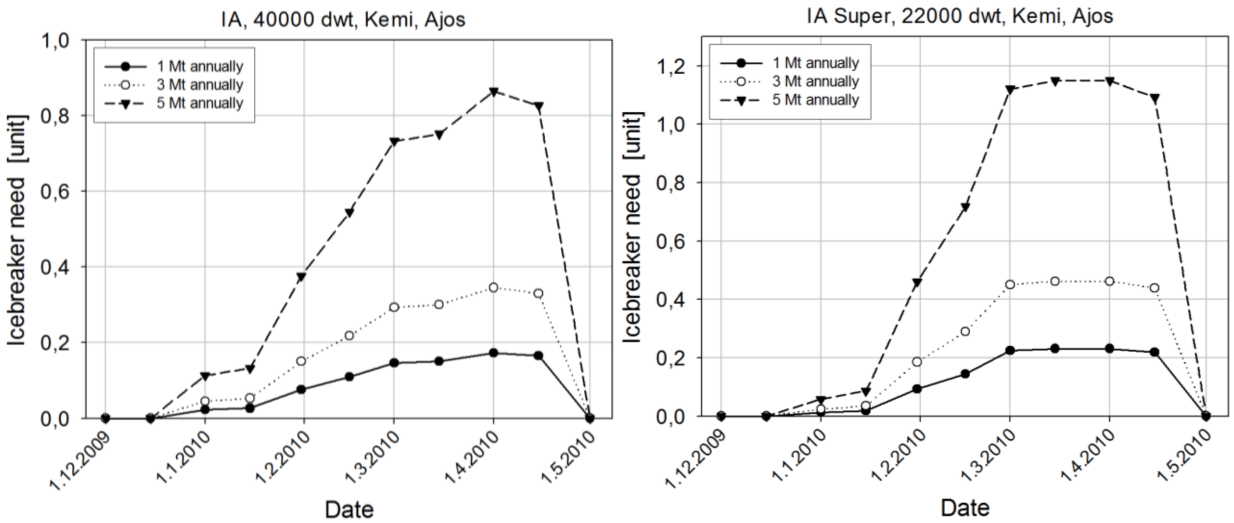

Fig. 15. The required level of icebreaker escort given as the relative usage time of one icebreaker.

Minimum requirements on the ships

There are three interacting parties influencing the decisions concerning a transport route: (1) The ship charterer gives a required amount of export per time unit (like 3 Mtpa) and also some requirements for the rotation, (2) the ship owner decides with what kind of ships the rotation and amount of export is met and finally (3) the maritime authorities decide about the icebreaker service levels. Fig. 14 shows that IA ships are escorted much, about 30 % more than the IA Super ships. Thus a large saving in the icebreaker need would result in combining the ships i.e. increasing the size of the IA Super variant. It is clear that a well functioning winter navigation system requires that all parties are dedicated to support year round shipping. Here the interaction between icebreaker service and requirements to be set on the ships is studied briefly.

If the ice performance of the ships is improved, it is clear that the icebreaker need (icebreaker usage) decreases. There are at least two ways to improve the ice performance of the larger bulk carrier; one is to make an ice breaking bow (similar to the bow of the 22 000 dwt ship) and the other is to just increase the propulsion power. The effect of these changes are investigated for the 40 000 dwt ship (the bulbous bow is replaced by an ice breaking bow and the propulsion power is increased from 12 MW to 15 MW) in case of 5 Mtpa export amount. The results of these changes on the icebreaker usage are shown in Fig. 16. Both changes have a similar effect of reducing the icebreaker need by 20 – 30 percentage units (reducing the usage by 1/5 to 1/3).

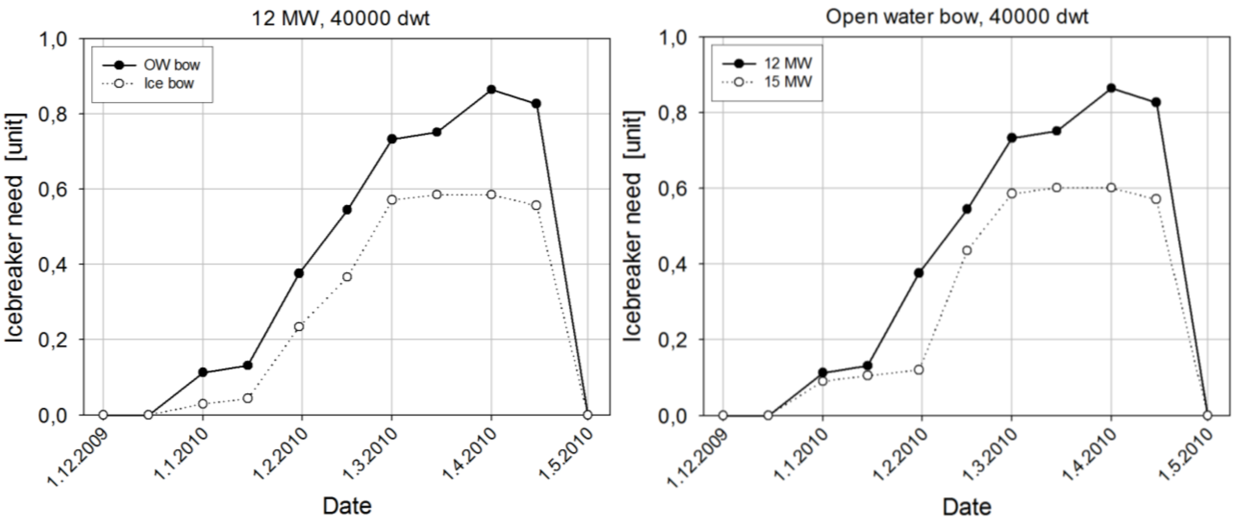

Fig. 16. The change in the icebreaker usage if an ice breaking bow is used or the propulsion power is increased for the ore carrier of 40 000 dwt.

The criterion which is an adequate performance level for the bulk carriers cannot be stated in absolute terms. The decision is influenced at least partly by how long waiting times for an icebreaker the required rotation tolerates. If the target is set that 0.5 icebreaker units are required then it can be concluded that the application of not only one of the above methods to improve the icebreaking capability are enough – power must be increased and also the bow improved. Naturally going above the calculated case, 15 MW, is also possible.

The beam also influences the ice breaking capability but its influence on the whole system was not investigated as this would have required redesign of the ships. As a rule of thumb it can be stated that in order to keep the ice breaking capability the same when increasing the beam, 1 MW of power should be added for each meter increase in beam.

5. CONCLUSION

The calculation of the icebreaker usage of the bulk carriers from Kemi is based on several assumptions concerning the escort speeds, ice data and ship dimensions. These assumptions can be investigated and, if necessary, revised and the calculations can then be redone. In order to be fruitful, the analysis should be based on correct assumptions as the roughly correct end results do not justify incorrect assumptions. Before, however, looking at the assumptions and the main results, some validity for the results is given by some observations.

The adequacy of the power selected based on the icebreaker escort required can be judged by experience from built ships. A good example of ships that require very little icebreaker assistance (Aro 2010) is given by the Transatlantic roro ships shown in Fig. 17. These ships navigate between Kemi, Oulu, Lübeck and Gothenburg. The main dimensions of these ships are

L = 190.8 m
B = 26.44 m
T = 7.8 m
P = 18 MW.

Thus the length and beam of these roro’s are comparable with the 40 000 dwt ore carrier. Their power is somewhat larger than that of the larger bulk carrier and beam a bit less (draught as such does not influence the ice performance much). Thus the conclusion of Fig. 16 that power of 18 MW (and slightly smaller beam) would make the ship almost independent of icebreaker escort can be seen to be roughly correct.

Fig. 17. A roro ship in the Transatlantic fleet of three ships; Transpaper, Transpulp and Transtimber (www.rabt.se).

The other validation data point is given by the statistics of the ore transport with the combiships Rautaruukki and Steel between Raahe on the Finnish side and Luleå on the Swedish side. The ice class of the combination is IA Super. The route of these tug/barge combinations is across the Gulf of Bothnia. The main data of the combination is given below.

L = 159.1 m (barge)
B = 27.2 m (barge)
T = 6.85 m (barge)
P = 7.66 MW (pusher)

The average voyage times during all winter months are shown in Fig. 18. The average voyage time (one way) is 9.9 h which means that time lost in ice on a round trip is on average 6.6 h (2 x (9.9 h - 6.6 h)). The average waiting time during the nine winters (2001 – 2009) investigated was noted to be 2.8 h (on a one way trip). This should be added to the time lost in ice but is not considered here. The time lost in ice for the Raahe-Luleå trade is quite close to the value of the 22 000 dwt ore carrier during February when the distance in ice is comparable to the Raahe – Luleå distance – even if the ice conditions towards Kemi are somewhat more severe than those in Raahe-Luleå route.

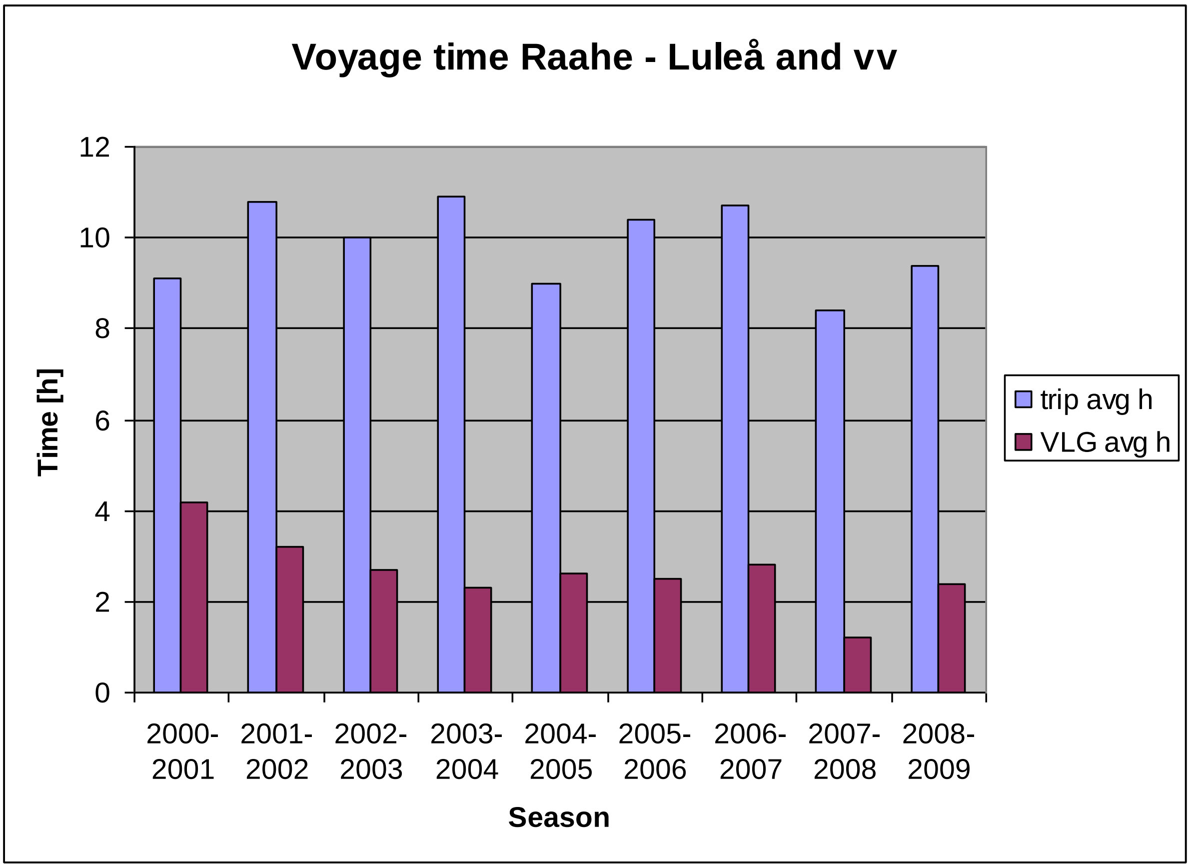

Fig. 18. The average voyage time one way between Raahe and Luleå. The average open water voyage time one way is 6.6 h (Berglund 2010).

As the end results of this study can be considered to be roughly appropriate, it is worthwhile to look at the assumptions and especially at the factors omitted from the study. These can be briefly listed as:

- The escort speeds are assumed to be given and not dependent on the escorting icebreaker or the ice conditions;
- The ice conditions are described by the equivalent ice thickness which is assumed to correlate with ship performance in ice;
- Ice conditions are divided into at most three different route segments which is a simplification of ice conditions – especially the first segment is not divided into the open sea and brash ice channel;

- The icebreaker usage does not take into account any convoy building i.e. escorts of more than one ship;
- The ship rotation is assumed to be uniform throughout the year and
- No optimization of the ship size/ice class/ice performance of the ore carriers has been carried out.

Some of these assumptions are easy to change if better data is available. Especially more detailed description of ice conditions is easy to do (it just increases the calculation work).

The main conclusion of the study is the amount of icebreaker support needed. This is measured by the relative time that icebreaker is needed during the ship rotation. If the export of ore is more than about 5 Mtpa, the trade ties up one icebreaker unit full time. There are three interacting parties influencing the decisions concerning a transport route: (1) The ship charterer gives a required amount of export per time unit (like 3 Mtpa) and also some requirements for the rotation, (2) the ship owner decides with what kind of ships the rotation and amount of export is met and finally (3) the maritime authorities decide about the icebreaker service levels. The icebreaker usage may be decreased by larger ore carriers and also by improving the ice performance of the ore carriers – this decision lies partly at the ship owner and partly with the charterer. The quantities joining the charterer and the ship owner are the required rotation and the freight rate. The maritime authorities offering the icebreaker services state often that the ships should meet some minimum requirements, this could be sated as a minimum power of about 15 MW. Of general interest is that there could be an optimum for the ship size, ice performance and icebreaker usage when the total costs (both icebreaker and merchant ship costs) of the trade are taken into account. With the present icebreaker fleet in the Gulf of Bothnia (three to four units), the added strain to escort times by opening the new ore trade results most probably in longer waiting times as new icebreakers are not likely built to serve one trade – this emphasizes the adequate ice performance of the assisted ships.

REFERENCES

Aro, I. 2010: Discussion Aro/Riska 4.2.2010.

Berglund, R. 2010: Raahe – Luleå, voyage statistics. An analysis made for The Finnish Traffic Agency.

MINTC 2009: Evaluation of the Transport Projects of the Kolari and Sokli Mining Projects. Ministry of Transport and Communications Finland, Working group report, Publications of the Ministry of Transport and Communication 29/2009, 40 p.

Nilsson, H. 2009: Iron Ore Mining in Cold Climate. Ice Day 2010, 10-11.2.2010, Tornio, Finland.

Ramboll 2009: Port of Kemi, Development of the Ajos Port, Environmental Impact Assessment Programme [in Finnish]. Study commissioned by the Port of Kemi, 39 p.

Riska, K., Breivik, K., Eide, S., Gudmestad, O. & Hildén, T. 2006: Factors Influencing the Development of Routes for Regular Oil Transport from Dikson. IceTech 2006, Banff, Canada, Paper no. ICETECH06-153-R0, 7 p.

Suojanen, R-A., Salmi, P. & Hakanen E. 2006: Study on Frequent Lines. Study commissioned by Baltic Icebreaking Management (BIM), 48 p.+app. 4.