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DEFINITION OF THE NEW ICE CLASS IA Super +

Sjöfartsverket
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FOREWORD

In its report no 60, the Winter Navigation Research Board presents the results from a research project to develop a new ice class IA Super +, which would be technically more advanced than the currently highest ice class IA Super. The purpose of this report is to describe the factors influencing the definition of this new ice class, and also to describe the economic advantages produced by the introduction of this ice class. The report as such does not take a stand to the pros and cons of the new ice class – its aim is simply to provide an analysis of the facts to support decision-making on this issue.

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

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Markku Mylly

DEFINITION OF THE NEW ICE CLASS IA Super+

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1. BACKGROUND

It has been suggested that the Finnish winter navigation system should be developed in view of technical advances in ice classed tonnage and that a new ice class should be defined above and beyond the currently highest ice class IA Super. This new ice class is called IA Super+. The purpose of this report is to describe the factors influencing the definition of this ice class, and also to describe the economic advantages produced by the introduction of this ice class. The report as such does not take a stand to the pros and cons of the new ice class – its aim is simply to provide an analysis of facts to support decision-making on this issue.

The Finnish foreign trade is highly dependent on smooth and well-functioning winter navigation. Some 80% of the volume of the Finnish foreign trade is transported by sea. Our imports and exports keep going round the year, and the trade of today does not tolerate fluctuations in transport systems or stops in schedules. A well-functioning winter navigation system is thus crucial.

The aim of the winter navigation system is to allow seaborne trade to run as smoothly, efficiently and economically as possible in the wintertime. Four factors can be distinguished in a well-functioning winter navigation system: icebreaker escort for merchant vessels, the number of visiting merchant vessels, the ability of merchant vessels to travel in ice, and traffic restrictions. These factors interact directly, the number of merchant vessels in need of icebreaker escort determining the number of icebreakers needed. There are other forms of interaction between these four factors which are less easy to define – for example, if traffic restrictions are made less severe, this will lead to an increased need for icebreaker escort, as there are more ships needing icebreaker assistance. This will result in longer escort distances and times. The traffic restrictions include a requirement of the lowest ice class, and the ice class includes the minimum performance requirement for ships in ice.

Dedicated efforts to develop the Finnish winter navigation system started in the beginning of the 1920's. At this time, the first Finnish ice class was set. The ice classes IA, IB and IC were defined in 1932, and at the same time, fairway dues were made dependent on the ice class. The aim was to develop winter navigation and especially the Finnish tonnage for year-round operation. Another aim was to reduce the dependency of the Finnish tonnage on icebreaker escort by defining a minimum ice performance in the ice class – the better the ice performance of a merchant vessel, the less she requires icebreaker escort. We can note that the aim of creating a well-functioning winter navigation system has been achieved, as seaborne trade is continuous throughout the year in all Finnish winter ports; and also as 47% of the Finnish tonnage has the ice class IA Super (1 Jan 2008) and only 9% have the ice class II (corresponding to an open water ship).

One cornerstone of the winter navigation system is that all ships fulfilling the requirements stated in the traffic restrictions (a minimum ice class based on the ice conditions and a minimum dead weight dwt) qualify for icebreaker escort. We should note that the Finnish-Swedish ice classes are intended for merchant ships that, during the open water season, compete with ships designed for open water conditions only. This means that neither the ice strengthening nor the ice performance requirement may be too high, as in this case, the competitiveness of ice classed tonnage would suffer vis-à-vis open water ships – the other side of the coin being that a large amount of icebreakers would lead to pressure to increase fairway dues.

A balance between the level of ice strengthening and traffic restrictions has been found based on experience. In the 1960's in particular, when year-round traffic to the Gulf of Bothnia increased, a large number of cases of hull ice damage occurred. The experience gathered of the ice damage lead to the definition of a strength level that has stayed almost unchanged from the beginning of the 1970's up till present time. The ice performance requirement was defined by setting a minimum propulsion power; this requirement has now been changed to one of a certain performance level in ice conditions. Both the strength and performance levels are increasing step by step based on the ice class from IC to IA Super.

It is the aim of this report to investigate the introduction of an ice class IA Super+, the factors influencing this introduction and also its possible consequences. In the economic calculations in the analysis below, a 16,000 dwt bulk cargo vessel is used as a reference ship. This type of a ship was investigated in an earlier study (BIM2006). In the earlier study, several versions of this ship were designed, and two of these versions are used here: the conventional ice strengthened version having a bulbous bow (version 0 in the earlier report) and the version having an ice-breaking bow shape (version A).

Director Ilmari Aro and Dr. Jorma Kämäräinen from the Finnish Maritime Administration acted as a support group for this study. Their analysis and expert comments on the investigation methods and results were indispensable for this study – their support is gratefully acknowledged. The remaining errors are naturally those of the author.

2. FACTORS INFLUENCING THE DEFINITION OF THE NEW ICE CLASS

2.1 Basis of Ice Classes

Performance Requirement

The required propulsion power of a merchant vessel in the winter navigation system – or the minimum ice performance level in the present rules – is set in view of smooth, continuous traffic without major delays. A quantity that aptly describes the continuity of winter traffic is the average time a merchant vessel has to wait for an icebreaker. The average of all waiting times in any year have varied between four and six hours (FMA2008). Ice conditions, the number of ships arriving, the number of icebreakers available and the ice performance of merchant vessels are some of the variables in the winter navigation system. The authorities can influence the latter two of these variables. The winter navigation system can be investigated as a logistic game where the merchant vessels sail from the ice edge into the ice for as long a distance as their ice performance allows (assuming that the ice conditions get worse towards the port of destination) and then wait for an icebreaker. The icebreakers then fetch the merchant vessels from the waiting position and escort them to their port of destination. This results in a waiting time that is typical of whatever ice conditions prevail at the time, depending on the number of icebreakers, number of merchant vessels and the ice performance of the merchant vessels (which determines the escort speed).

As an example of a holistic analysis of a winter navigation system, see the results in Fig. 1. This presents a slightly modified version of the analysis performed for the winter navigation system of Estonia (FMA2005). The waiting time for an icebreaker versus the required propulsion power of merchant vessels is shown using the number of available icebreakers as a parameter – the calculation was made using the number of ships arriving in Estonia as an input figure, assuming an average size and type for the merchant vessels. The waiting time was extrapolated to propulsion power that corresponds to a vanishing waiting time; this extrapolation is actually incorrect, as the waiting time will not go down to zero with increasing propulsion power. There will always be ice conditions, such as large ridges, that will stop any normal merchant vessel, after which an icebreaker is not immediately available. This definition based on average waiting times and an extrapolation to zero waiting time forms, however, one possibility of defining the new ice class IA Super+.

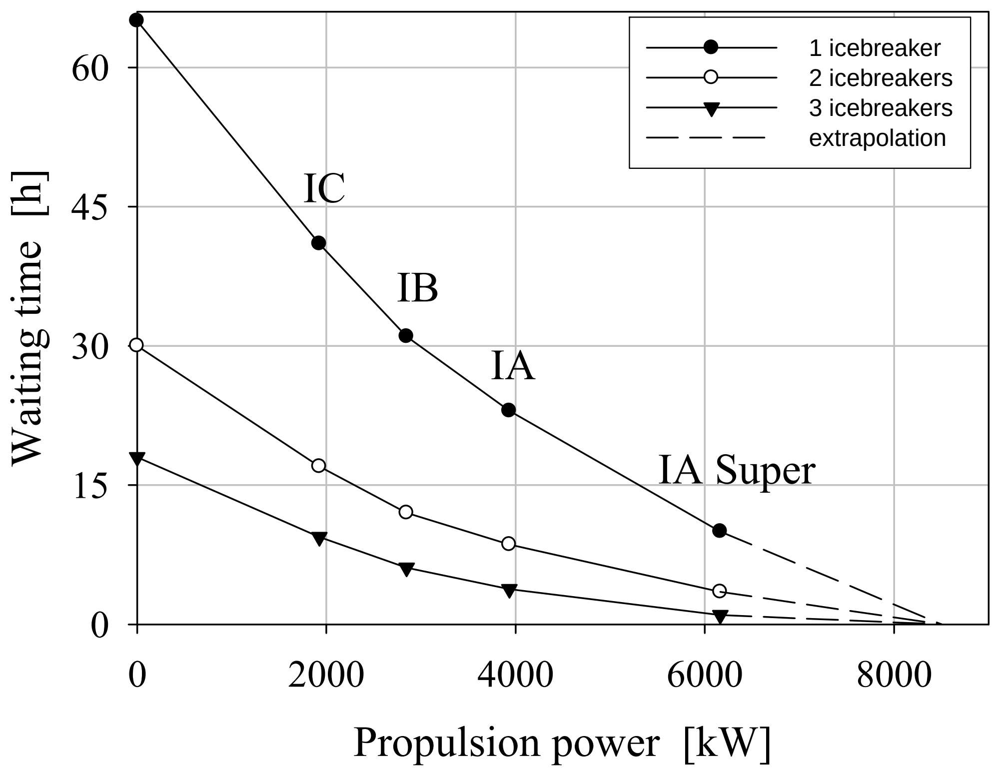

Fig. 1. The waiting times for an icebreaker in a winter navigation system modified from the Estonian system shown in terms of propulsion power and using the number of icebreakers as a parameter. The propulsion power '0' refers to open water ships that cannot sail in ice at all. The Figure corresponds to ice conditions in a severe winter.

Figure 1 suggests – even if the results have been slightly modified from the original – that the required ice performance of a vessel in ice class IA is adequate; for if the traffic restrictions require an ice class IA, the waiting time in the prevailing ice conditions is 4 hours with three icebreakers available. A waiting time of 4 hours is generally considered acceptable. If there only were two icebreakers in operation, the waiting time for an IA ice class vessel would be about 9 hours, which in the Finnish winter navigation system is considered excessive. The analysis performed above also suggests that if three icebreakers were operating in a winter navigation system, and the maximum waiting time target were set at 6 hours, the ice performance requirement for ice class IA could be relaxed slightly (at least for the ship analysed here), but if there were two icebreakers, the performance requirement should be increased.

The aim of this investigation is to define a new ice class; an ice class defined as vessels that do not need icebreaker escort, and thus bringing the waiting time for an icebreaker down to zero. The analysis above would suggest that for an average ship in Estonian traffic, a propulsion power of 8,500 kW would be sufficient for independent operation. Whether this power is actually sufficient – and the reasoning correct – will be investigated later in this report.

Strength Requirement

The correct strength requirement level for a ship's hull and machinery depends on a balance between factors influencing safety and economy, and thus the correct strength level is a matter which must be set by the authorities. As ice loading is statistical, ice loads even larger than the calculated ones can be encountered, if the exposure to ice loading is long enough. In principle, a certain risk level must be used as a basis for ice rules, for example 'one ship out of a hundred sustains once in a 10-year period ice damage of a certain extent'. The first part of this definition gives the accepted probability level of the ice load, and the second part, the severity of the damage, defines – when the load is determined applying the given probability – the scantlings (for example the plating thickness).

The definition of the required strength level applying the risk level approach is at present based on experience of ice damage. A certain ice load level has been defined in the rules, and experience with ships built to these rules has shown that more significant ice damages are sustained infrequently sustained. The correct strength level has varied somewhat over the years, but the rule change based on analysing ice damages that occurred in the 1960's has proved to be correct, and at the moment, the Finnish-Swedish Ice Class Rules only need some minor adjustments.

When a risk level is used as a basis for ice rules, an interaction is introduced between the assumed most significant ice damage (or more correctly, the response of the structure), loading frequency and scantlings. If the accepted ice damage is minor, such as a small dent in the plating, the load frequency can be quite elevated without the risk level being too high. Similarly, if the accepted damage is major, the frequency of the loading causing this damage (structural response) must be low in order to keep the risk level low enough. In the analysis of a risk-based design discussed above, ice conditions have been used as a parameter, i.e. the ice conditions (ice thickness and the amount of ice cover) influence the probability of loading. The ship size and power also influence the loading probability.

The connection between loading, the design criterion (extent of damage) and probability of loading is shown in Fig. 2. The left side of the blue graph shows the design criterion (which in this case is the collapse of the plating); at a certain load (line load) and with certain scantlings, the accepted damage will be sustained and the plating collapses. On the right-hand side is shown the connection between loading probability (given as the return period of the loading) and load magnitude. This return period was obtained through ice load measurements onboard a ship navigating to the Gulf of Bothnia. The Figure illustrates a situation where 18-mm thick plating will collapse under a load of 1,800 kN/m – which occurs about once every 400 days.

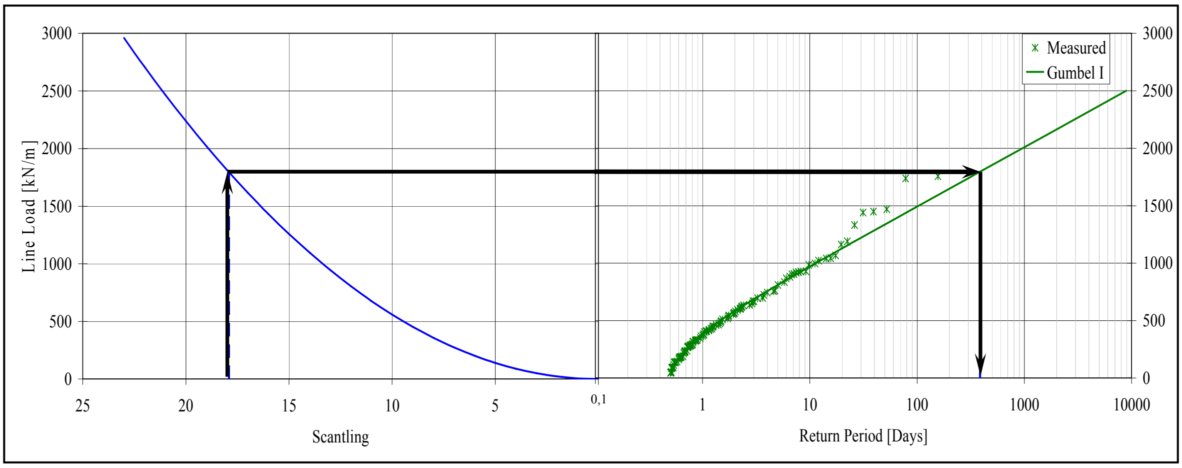

Fig. 2. Estimation of the risk level for a given ship (from scantlings to the frequency of the defined ice damage). The direction of arrows may be reversed, proceeding from a certain load frequency through a preset damage to scantlings (SAFEICE, D9-2).

The definition of the load level in the present Finnish-Swedish Ice Class Rules is based on an elastic limit – the stresses in all structural members should remain below the yield limit. This has been observed to correspond to a loading that is encountered in level ice of about 1 metre in thickness (in case of ice class IA Super). Measurements suggest that this level of ice loading is exceeded approximately five times a year in a ship that sails regularly to the Gulf of Bothnia. The load frequency graph shows that this risk level also corresponds to smaller dents in the plating every second or third year.

As mentioned above in passing, the strength level in the Finnish-Swedish Ice Class Rules is set to correspond to the loading encountered in level ice of a certain thickness; in ice class IA super, this thickness is 1 m, and in the lower ice classes IA, IB and IC 0.8 m, 0.6 m and 0.4 m, respectively. This thickness has to be interpreted as an equivalent ice thickness, which is described in Chapter 3.2. If the vessel can navigate in ice thicker than this because of its increased ice performance, the strength requirement has to be changed in principle. In the ice rules, the factor $k = \sqrt{P \cdot \Delta}$, where P is propulsion power and Δ displacement, influences ice loading. This coefficient has been justified by the fact that it describes the ability of a ship to navigate efficiently in ice – the power sets the speed in ice, and the displacement the ability to maintain the speed in ice. If the ships in the new ice class can navigate in thicker ice, their speeds in average ice conditions are increased. An important question is whether the increase in the design loading induced by the increase in factor k adequately describes the increased loadings induced by an improved performance in ice.

2.2 Aim of the New Ice Class

The initiative to define a new ice class IA Super+ is primarily based on the rationale that a ship navigating independently in ice rarely if ever needs icebreaker escort in the Baltic, thus bringing cost savings in the winter navigation system. This way, ships navigating independently in ice will reduce the need to invest in icebreakers especially in dense liner traffic, such as the route between Raahe – Luleå. A major increase in seaborne traffic in the Gulf of Bothnia will take place, if the planned mine projects around Kolari proceed. The increase in the required transport capacity has been estimated at 13 million tonnes annually – corresponding to one 40,000 dwt ship arriving daily.

If the aim of the new ice class is to reduce dependence on icebreaker escort services, the ice performance requirement of the ice class IA Super+ must be set to ensure that this class is only granted to ships that can navigate independently in ice. Additionally, we should note that icebreaker dependency can only be reduced in sea areas where icebreakers operate for a longer period – at least 3-4 months each winter. The frequency of traffic must be high enough for conventional ships in present ice classes to occupy one icebreaker full time. Several slightly different ideas about the aims of the new ice class have been presented. At least the following aims have been mentioned:

2.2.1. The introduction of a new ice class IA Super+ will create a possibility for shipowners to invest in better, independently operating tonnage and operate their ships independently of icebreaker services;

2.2.2. If shipowners use independently operating ships, savings in the icebreaker services will be obtained, and maritime traffic will be made more continuous and efficient;

2.2.3. An independently operating ship can also operate in the Arctic waters. This will give shipowners potential to operate in Arctic trade.

The first two objectives are interlinked; if the merchant fleet performed better in ice, less icebreaker escort would also be needed. A better merchant fleet will also increase the safety of maritime transport. In the first two objectives, advantages to the society alone of the new ice class are apparent. The aim is to achieve savings by shifting some of the infrastructure costs to the operators, or shipowners and charterers and giving some economic incentive to do this. The third objective would also necessitate, in addition to requirements addressing ship performance in ice, changes in the strength requirements, as ice loading encountered in the Arctic waters may be more severe than the loading encountered in the Baltic. Based on the definition of the ice classes in the Finnish-Swedish ice class rules, the first two objectives would also induce a need to increase the strength of the ships.

Above, a new ice class IA Super+ was defined as a prerequisite for independent progress in ice. What this means is that a ship having the new ice class will not need any icebreaker escort. However, as there will always be ice conditions that in practice will stop any vessel – such as large ice ridges – independent navigation means that the ship can always extract herself and continue her progress, even if she is stopped in heavy ice. This extraction ability can for example mean heeling tanks, the use of which enables the ship to back off from a large ridge; or bow propellers, with which the ship can disperse the ridge where she got stopped and thus continue her progress, albeit slowly. In this context, it is important to distinguish between a 'ship with a good ice performance' and 'a ship operating independently in ice'. A ship with a good ice performance – typically of the ice class IA Super – will need icebreaker escort during the worst ice conditions, but an independently operating ship should never need it.

2.3 Advantages of the New Ice Class

In order to be beneficial both for the society providing the infrastructure and all actors in the maritime trade, some incentives to adopt the new ice class should be defined. Several possibilities have been suggested, the following among others:

2.3.1. Ships in the new ice class IA Super+ are granted a lower fairway due unit cost than those in ice class IA Super;

2.3.2. Shipowners who invest in IA Super+ ice class ships are given investment support;

2.3.3. Ships navigating independently in ice are given an icebreaker status, and thus part of the Finnish Maritime Administration's budget reserved for purchasing icebreaker services can be transferred to these ships;

2.3.4. If ships in ice class IA Super+ are only used in a certain sea area, these ships could be given some regional support;

2.3.5. The use of ships navigating independently in ice may make the maritime transport mode more lucrative compared with other transport modes, and thus this potential modality change would be a reason worthy of support.

Of the possible support instruments listed above, only the first and third one can be analysed in more detail here. Other instruments of supporting maritime traffic with independent ships were investigated in the report FMA2007. The conclusion there was that the current support instruments are not particularly applicable, at least not directly. As these other instruments are not analysed further, only some comments on them are in order:

- Investment support is part of the government's economic policy, which is outside the scope of this investigation;
- Even if a ship in ice class IA Super+ operates independently and continuously in a certain sea area, other ships of lower ice classes in this area will need icebreaker escort. It will thus be difficult to include these IA Super+ ships in the icebreaker fleet, if other ships will be needing icebreaker escort in the same sea area;
- An implicit basis for the definition of this new ice class is liner traffic between Raahe and Luleå. This route is within the EU's regional definition of 'Very scarcely populated areas', but the applicability of support for the maritime trade should be checked. In general, regional support is not part of this investigation;
- Support for modality change is linked with EU transport policies, but establishing which transport flows could be shifted from land to sea using ships operating independently in ice would be difficult.

In the following, we will focus on assessing the possibility of using fairway dues and/or ice breaking support as an incentive for investing in ships in ice class IA Super+.

3. DEFINITION OF ICE CLASS IA Super+

The ice class defines an appropriate strength level and also, in the Finnish-Swedish Ice Class Rules, the minimum performance in ice of a ship. The strength level is often defined with reference to a nominal ice thickness; the Finnish-Swedish ice class IA Super, for example, corresponds to level ice of 1 m in thickness. Several other ice class systems use similar thickness reference definitions, but large variations exist, mainly because of the differences in strength criteria. The ice performance requirement is only stated in the Finnish-Swedish and Russian rules. The reason for this is that only in Finland, Russia and Sweden is a winter navigation system based on icebreaker escort used. It is thus clear that the number of icebreakers required will be smaller, if merchant vessels have some ice performance capability.

The definition of ice class IA Super+ can be based on ship performance in ice (objectives 2.2.1 and 2.2.2), as these objectives would bring savings in the ice breaking service costs. If objective 2.2.3 is to be fulfilled, too (the ability to navigate in Arctic conditions), the ship strength also has to be clearly increased. The ways in which the new ice class could be defined are analysed in the following – including the consequences of the definition.

3.1 Ice Performance Requirement

A succinct definition of a ship operating independently in ice is not easy to find. The basis of this definition must be that the ship can proceed in all ice conditions in its operating area without icebreaker escort. A definition given in this way will fulfil objective 2.2.2. The case can also be analysed based on an average situation; the ship is required to have a certain minimum speed in the most severe average ice conditions of the operating area during an average winter. The ice conditions can be described using the ’Equivalent ice thickness’, which is discussed below. This average way of describing ice conditions has the disadvantage that, as there are large local variations in the ice conditions, there always is a significant probability of large ridges stopping the vessel. In this situation, the ship must, in order to manage without icebreaker assistance, get moving again and in one way or another traverse these large ridges.

One suitable measure for performance in ice is provided by the minimum speed in a specified equivalent ice thickness. The basic requirement might be that the ship can also move in the greatest equivalent ice thickness that may be encountered in the operating area. The phrase ’can move’ commonly refers to a speed of at least 3 knots. Let us analyse the situation using the reference ship mentioned above and used in the previous analysis (BIM 2006). This ship is a bulk carrier with a dead weight of 16,000 dwt, length of approx. 150 m and beam of 23 m. Four different bow shape versions are used in this study. These have been labelled based on the stem angle φ:

- ’bulb’ - A common ice strengthened ship that has a bulb. This corresponds to version ’0’ in the earlier study
- ’MV ice’ - A common ice strengthened ship that has an ice breaking bow (stem angle $\varphi = 45^{o}$)
- ’Uikku’ - An ice strengthened ship that has a bow similar to MT Uikku ($\varphi = 29^{o}$)
- ’26’ - An ice strengthened ship that has an excellent ice breaking bow ($\varphi = 26^{o}$). Corresponds to version A in the earlier study.

- 'IB' - A ship with an icebreaker bow ($\varphi = 19^{o}$).

The power requirement of these ships is now investigated in certain equivalent ice thicknesses. These equivalent ice thicknesses are selected to correspond with the maximum ice thicknesses in an average and severe winter in the Gulf of Bothnia and the Gulf of Finland. These equivalent thicknesses are:

- Gulf of Finland, average winter H_{eq} = 60 cm
- Gulf of Finland, severe winter H_{eq} = 100 cm
- Gulf of Bothnia, average winter H_{eq} = 85 cm
- Gulf of Bothnia, severe winter H_{eq} = 130 cm

The Gulf of Finland is included in the study for reference, even if the length of the winter season there does not fulfil the requirements stated in 2.2. For the results power requirement calculations in ice conditions and the ships mentioned above, see Fig. 3. The results show that during a severe winter in the Gulf of Bothnia, a normal ship with a bulb will need a propulsion power exceeding 40 MW, but if the bow design is better suited to ice conditions, a power of slightly less than 30 MW is sufficient. The corresponding figures for the Gulf of Finland are 27 MW and 16 MW.

The analysis shows that the definition of the ice class IA Super+ based on independent operation leads to a large propulsion power – even larger than that in ro-ro ships with a high open water speed. Some of the ro-ro ships operating in the Gulf of Finland have a propulsion power that is only slightly below the power required for independent operation in ice during a severe winter in the Gulf of Finland. There also is, however, a trend among shipowners to lower ship speeds as fuel oil prices are likely to increase.

In this context, we should mention that Lloyd's Register already has a definition for a new ice class 1AS FS(+). The strength requirements of this ice class are the same as those of ice class IA Super, but the propulsion power requirement is different. Applying Lloyd's Register's new ice class to the reference vessel used here (version 'bulb'), a propulsion power requirement of about 8,500 kW is obtained. This corresponds to a 3-knot speed in level ice of 55 cm in thickness. Ships in this new ice class are thus not capable of navigating independently in the Gulf of Finland during harsher winters.

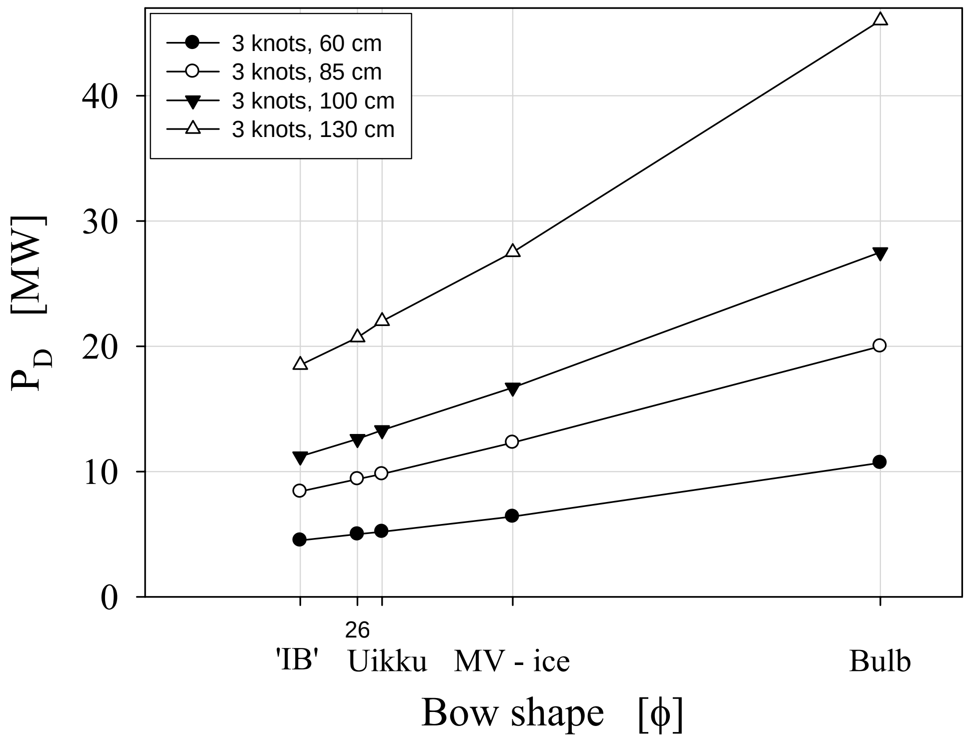

Fig. 3. The propulsion power requirement for ship versions defined in this report in different ice thicknesses.

The classification of winters into different categories revealed one difficulty in defining the new ice class. Should the objective be defined so that ships in the new ice class never need icebreaker escort – even during severe winters – or does it suffice to be independent during average winters? This decision has a great influence on the power requirement. One alternative would be to stipulate that ships in the new ice class must pay for any icebreaker support that they need, as they pay a lower fairway due.

3.2 Strength Requirement

The strength requirement in the Finnish-Swedish Ice Class Rules was set to correspond to operation in a certain level (or rather equivalent) ice thickness. This varies from 1 m for the ice class IA Super to 40 cm for the ice class IC. These ice thicknesses are to be interpreted as equivalent ones; if a ships is navigating in level ice of 40 cm in thickness, this will result in the same load level as irregular ridged ice of an equivalent thickness of 40 cm. Out at sea, the ice cover only contains level ice in small patches; in practice, all ice is deformed and ridged. There are several definitions for an equivalent ice thickness, and scientists are not particularly unanimous about the definition. A simple definition for an equivalent ice thickness that gives roughly correct values (validated by full-scale measurements) is the average thickness of all the ice.

Widely different opinions exist about the equivalent ice thickness related to ice classes. For a Russian interpretation of equivalent ice thickness associated with ice classes, see Fig. 4. These thicknesses are somewhat low for the Finnish-Swedish ice classes, as it has been noted in Finland that the ice class IA Super corresponds fairly well to the ice thickness of

1 m stated in the ice rules. However, the Figure gives a good insight in the differences between various ice classes.

The different ice classes can be compared based on structural strength; structural weight in particular can be used as the quantity for comparison. For this type of a comparison between ice classes based on structural weight, see Fig. 5, where the quantity F_{np} represents weight. The comparison shows that ice class IA Super roughly corresponds to the Russian ice class LU5 (Ice5) and ice class PC6 in the new IACS Polar rules. If the objective for the new ice class IA Super+ is safe navigation in Arctic waters, the required strength should be similar to PC5 – LU6 (cf. Fig. 4 and the values given for equivalent strength in previous Chapter). This would mean a large increase in strength from the ice class IA Super.

The hull structure of Finnish icebreakers can be considered an example of adequate and sufficient structural design. The weight of the ice strengthened part of the hull structure of IB Urho is approx. 30% greater than the weight of the same hull designed for ice class IA Super. Based on estimates given in Fig. 5, the increase in hull weight of an ice class LU6 ship compared with an IA Super ship is about 44%, and the corresponding increase for ice class LU7 is 93%. To sum up, we can say the strength requirement that would be sufficient for Arctic waters would roughly double the weight of the hull ice strengthening – and this increase in weight would roughly increase the total hull weight by about 10%.

How much should the hull strength be increased if the definition of ice class IA Super+ were based on objectives 2.2.1 and 2.2.2? The first estimate to answer this question can be obtained from the equivalent thicknesses given in previous Chapter and from Fig. 4; the adequate strength level would correspond to ice class LU6. If, on the other hand, ships in ice class IA Super+ are built to be capable of navigating in Arctic waters (objective 2.2.3), the strength level of the hull should correspond to ice class LU7.

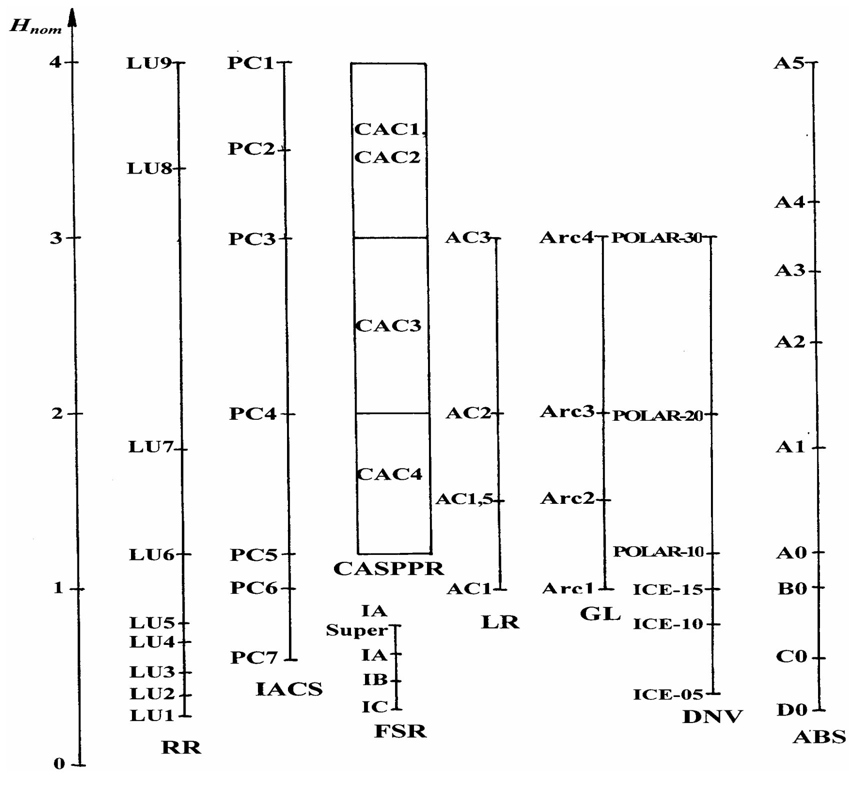

Fig. 4. The equivalent ice thickness H_{nom} related to different ice classes (Appolonov et al. 2007).

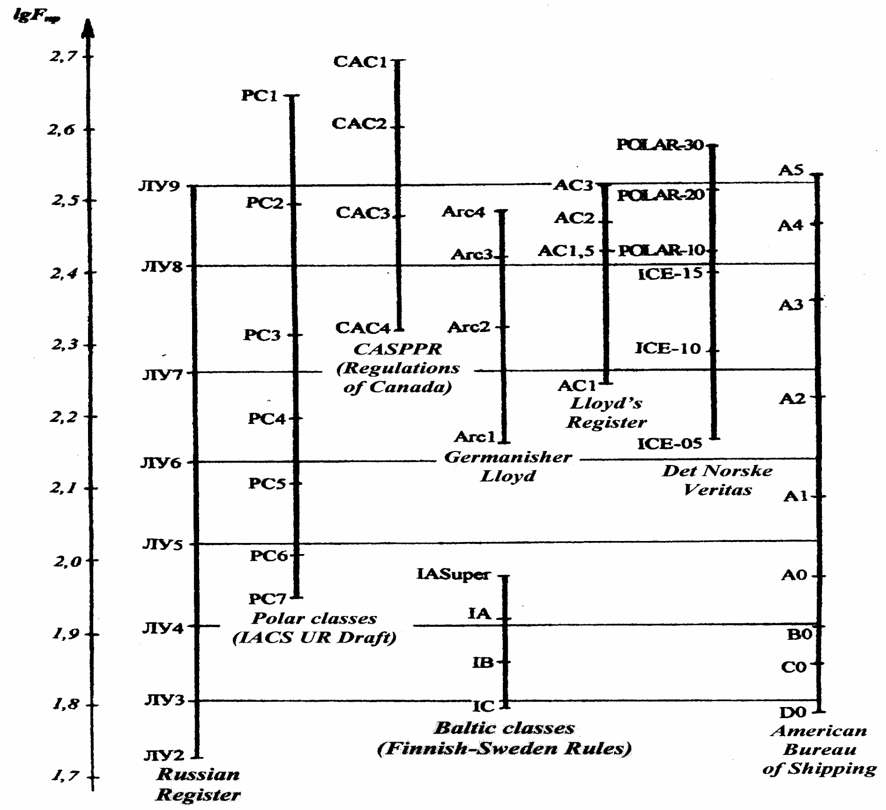

Fig. 5. Comparison between different ice classes based on hull weight (Appolonov et al. 2007).

4. CHANGE IN FAIRWAY DUES

4.1 Current Fairway Dues

The current fairway dues have from 1.1.2008 been based on a unit price for net tonnage (NT) and the ship ice class – additionally, passenger and cargo ships have different unit prices. For a comparison between fairway dues for different ice classes versus net tonnage, see Fig. 6. As the NT is a somewhat abstract quantity, the magnitude of the fairway due can be estimated once it is known that for a (bulk) cargo vessel, the ratio between dead weight and net tonnage is very roughly approx. dwt/NT ~ 3, and the net tonnage of a 170 m long passenger car ferry is about 22,000 NT. The fairway due is paid annually for a maximum of 10 visits to Finnish ports, and for 30 visits for passenger ships. The 16,000 dwt reference ship used in this study would pay annual fairway dues amounting to about €62,000 .

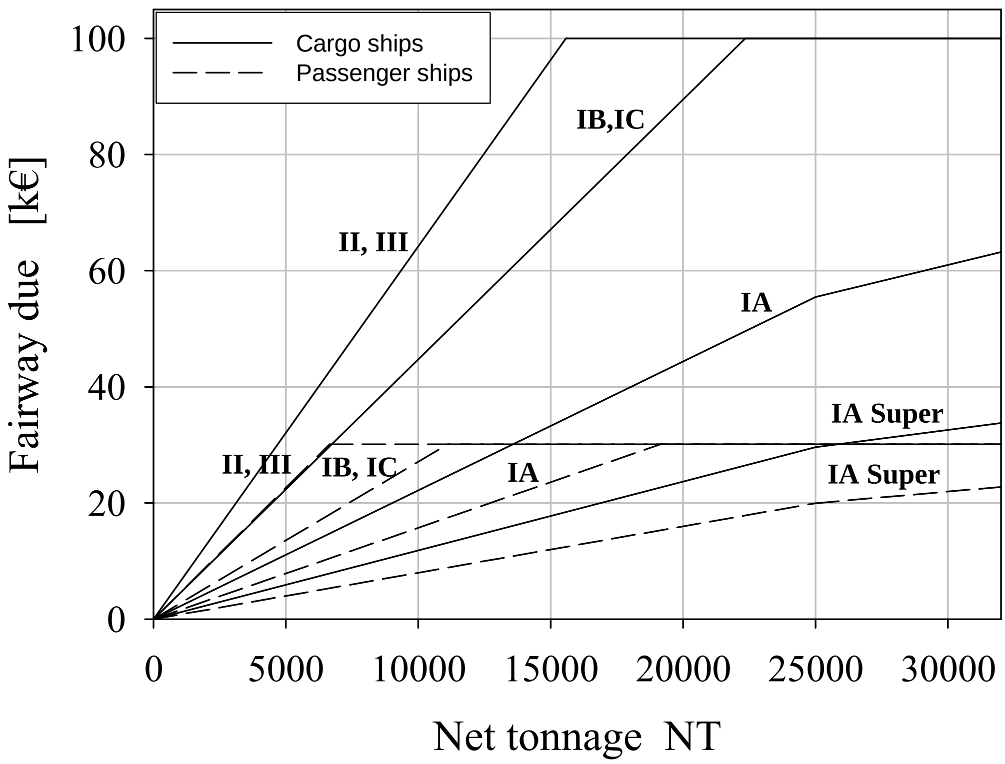

Fig. 6. The fairway dues of ships with the ice class as a parameter. The lowest broken line for both ship types corresponds to ice class IA Super, and the lines above that ice classes IA, IB and IC both II and III.

4.2 Change in the Fairway Dues

The definition of the unit price of the fairway dues for the new ice class IA Super+ should be based on the requirement for ships in this ice class to manage without icebreaker escort. The most straightforward way to change the fairway dues based on the above definition is to decrease the unit price for ice class IA Super+ further from the unit price of ice class IA Super. If the steps by which the unit price goes down with the decreasing ice class (IB,IC→IA and IA→IA Super) are kept uniform, the new unit price for a cargo vessel in the new ice class would be €0.66/NT.

Another way of defining the fairway due for ice class IA Super+ is based on an estimate of to what extent the fairway dues are used to cover costs arising from icebreaker services. This portion would not be payable by ships in ice class IA Super+, as they do not need icebreaker services. The fairway dues cover about one third of the expenses of the Finnish Maritime Administration (FMA annual reports 1997-2000), whereas the net operating costs of icebreakers used to be (i.e. before Finstaship was established) about one quarter of the income from fairway dues. If the capital costs associated with icebreakers are taken into account, the total of all icebreaking costs correspond to about one half of the annual expenses of the FMA. If this last estimate is used as a basis – and assuming that the other half of the costs are related to other infrastructure costs, an estimate for the unit price of the ice class IA Super+ fairway due is about €0.7/NT (or one half of the unit price of the ice class IA Super). These two estimates give values that are very similar to each other.

The unit price of the new ice class was defined above without paying attention to the fact that the total income from fairway dues must be a fixed portion of the FMA's total income. Thus the new fairway due cannot be defined without analysing the total income from fairway dues. If the volume of foreign trade is constant and some of it is carried by IA Super+ ships, in case some dues are lowered, some others must be increased. A more exact analysis of this type is, however, not included in this preliminary investigation.

5. ADOPTION OF THE NEW ICE CLASS

In this Chapter, the consequences of adopting a new ice class are investigated. The objective is to investigate these consequences in several perspectives, making it possible to base decisions on a sound rationale.

5.1 Definition of the New Ice Class

Three objectives were set in previous Chapters for the definition of ice class IA Super+. The objective of reducing the need for icebreaker services is the only one of these that has some impact on reducing infrastructure costs. The objective of an increased usability of ships in Arctic waters would result in a direct support to shipowners who operate not only in the Baltic but also in the Arctic Seas. This will not directly serve the Finnish foreign trade. An increase in the strength level would improve the safety of winter navigation, but even this target is not significant, as the level of maritime safety is also high in the winter – this is proven by accident and damage statistics from average winters that followed the relatively severe winter of 2003.

The basis of the definition of ice class IA Super+ in view of infrastructure support must be that ships in this ice class do not need icebreaker services and they should not pay for these services through fairway dues. One consequence of this definition is that, if these ships in exceptional ice conditions need icebreaker services, they would have to pay for them. This can, for example, be justified by the rationale that if the prerequisite of the support (a decrease in fairway dues) is not fulfilled, some of the support must be paid back. One question that has often been posed is if all ships that do not need icebreaker assistance in the winter could pay the new reduced fairway due. Reasons for a ship not needing icebreaker escort could include such as the fact that the ship navigates in an area where the fairways are always broken and the ship's propulsion power is sufficient for these conditions. In this case, the requirement of independent ice operation in <u>all</u> conditions is not fulfilled.

In case of a common merchant ship with a bulbous bow, the requirement of independent navigation in all ice conditions leads to large propulsion powers; for the reference vessel operating in the Gulf of Bothnia, the required power is 46 MW and in the Gulf of Finland 27 MW. If the reference vessel is designed for ice conditions (an ice-breaking bow), the required propulsion powers are 21 MW and 13 MW when operating in the Gulf of Bothnia and Gulf of Finland, respectively. This analysis shows that independent operation requires a great propulsion power of a normal vessel, but if a hull shape designed for ice performance is used, the required propulsion power can be considered reasonable. The requirement of independent operation includes, apart from a minimum power, also a requirement of not getting stuck in the largest ice ridges present in the area. This requirement can be fulfilled in many ways, and incorporating this in the ice class definition is a challenge.

5.2 Two Possible Ice Class Definitions

Based on the above analysis, two possible definitions of the new ice class IA Super+ emerge:

Definition based on an average winter

IA Super+ ice class ships are defined as ships that can operate independently in all ice conditions in the operating area during an average winter. As these ships need icebreaker escort during the most severe winters (a severe winter is defined as one occurring every tenth year), they cannot be granted icebreaker status, and thus the lower fairway due unit price is the only support instrument available. A consequence of this, as is shown below, is that the investment is not profitable, at least not in case of bulk cargo ships. Another further problem with this definition is that in the Gulf of Finland for example, many ro-ro vessels would get this ice class based on their ice performance (these ships have a high propulsion power in order to maintain high open water speed). If this is allowed, the calculation of the fairway due for ice class IA Super+ must take this into account when assessing the total income from fairway dues.

Definition based on a severe winter

IA Super+ ice class ships are defined as ships that can operate independently in all ice conditions in the operating area, also during a severe winter. In this case, these ships can obtain not only a lower fairway due but also an icebreaker status. The support based on the icebreaker status can be in the same order of magnitude (see reasoning described below) as the extra operational and capital costs of an ice class IA Super+ ship compared to a normal ice-strengthened cargo ship. A problem with this definition is finding an applicable route where this icebreaker status can be utilized; a route where icebreaker services would not be needed after the introduction of ships in this new ice class.

5.3 Impact of Economic Incentives

In this Chapter, we will investigate the impact and applicability of economic incentives. There are two possible incentives: lowering the fairway due and also transferring some funding from the budget for icebreaker services to ships that are granted an icebreaker status. Only the capital costs associated with ice class IA Super+ are investigated here, but in a more detailed study, the operating costs should naturally also be taken into account. The capital costs (ship price) are based on estimates given in an earlier study (BIM2006) for different versions of the reference ship (Tables 13 and 14 on p. 42). These prices are replaced by prices of the ship versions investigated here, assuming machinery price to be directly proportional to machinery power and adjusting other price positions slightly based on the increased power. By comparing ships with a bulbous bow and an ice-breaking bow with the basic version of the earlier study ('version 0'), the price difference between the different reference ship versions and the basic version is obtained. The basic version was an ice-strengthened ship in ice class IA Super that needs icebreaker escort. The results are presented in the Table below (where the figures corresponding to the Gulf of Finland are given for reference – even if the winter here is not long enough for the introduction of the new ice class).

			Ice-breaking bow		Bulbous bow	
Sea area	Ice conditions	H_{eq} [cm]	P [MW]	Extra cost [M€]	P [MW]	Extra cost [M€]
Gulf of Finland	Average	60	8.3[1]	0.3	10.7	3.3
	Severe	100	12.9	6.1	27.5	24.5
Gulf of Bothnia	Average	85	9.6	2.0	20.0	15.1
	Severe	130	21.4	16.8	46.0	93.0

[1]Power based on open water requirements

What stands out directly in the above Table is that a ship with a bulbous bow also operating independently during severe winters in the Gulf of Bothnia is in practical terms impossible to realize.

The consequences of changing fairway dues

The change in the fairway due unit price, as defined above, would bring the reference ship an annual saving of about €31,000 compared to a ship in ice class IA Super. The price of the ship in ice class IA Super+ would be higher than that of a IA Super ship according to the Table above. This Table shows that a ship in ice class IA Super+ with an ice breaking bow that operates in the Gulf of Finland in all winters would be about Euro 6.1 million, i.e. about 14% more expensive than an ice strengthened (ice class IA Super) ship with a bulbous bow (version ’0’). The cost of a similar ship, aimed for operation in the Gulf of Bothnia in all winters, would be about Euro 16.8 million,i.e. about 39% more than that of the basic version. As the total savings in fairway dues during the ship's lifetime are about €800,000, these investment costs in the new ice class cannot be covered by savings in the fairway dues in the Gulf of Bothnia traffic – not even if ice class IA Super+ did not pay fairway dues at all. The above prices are based on the cost level in year 2006, and ship prices have increased from this level – even if the current trend again is towards decreasing prices (November 2008).

The price estimates of the different versions of the reference ship also provide an answer to the question of a support level that would make the investment in the new ice class profitable, if the fairway dues for the new ice class are lowered as discussed above. The annual extra costs in the Gulf of Finland traffic are about Euro 250,000, and the fairway due savings Euro 31,000; consequently, in the Gulf of Finland traffic, the extra support should be about Euro 220,000 - and naturally, considerably more for the Gulf of Bothnia traffic. We should also remember that these figures only contain the capital costs.

The consequences of granting an icebreaker status

The idea is that ships in the new ice class IA Super+ could be granted an icebreaker status, consequently channelling some of the funding reserved for icebreaker services to these ships. This mechanism could only function on routes where other, only ice strengthened ships that need icebreaker services do not operate. At the most, this support could correspond to the annual costs of one icebreaker, and naturally this amount should be equally divided between all ice class IA Super+ ships operating on this route. The daily fuel costs of an icebreaker are about €8,000/day, and the daily cost is about €30,000/day. If the icebreaker would operate on a route for two months, the total costs of the icebreaker would be about €2.3 million. This sum is of the same magnitude as the extra cost of investment in a IA Super+ ship capable of independent navigation even in severe winters in he Gulf of

Bothnia – this sum is €16.8 mill. (which should be discounted in annual capital costs). We should bear in mind the fact that this extra cost only includes capital costs; the IA Super+ ship's fuel costs are higher than that of the basic liner version, and a rough estimate of these costs is about €300,000 more than those of a ship that is ice strengthened only and needs icebreaker escort.

Granting an icebreaker status cannot be restricted to one special case, but the support should be available to all ships fulfilling the requirements. Routes where IA Super+ ships only are operating are not many; actually, traffic between Raahe and Luleå is the only example – and even on this route, ore carriers are not the only ships calling to these ports. Another problem with granting an icebreaker status is that these IA Super+ ships should never need icebreaker escort, and if they do need it in some special circumstances, the icebreaker escort costs should be settled by the escorted ship. The market price of icebreaker escort is not available, but it should be roughly about €5,000/h, based on average icebreaker costs and escorted hours.

6. SUMMARY

As a summary of the whole investigation discussed in this report, a basic case can be presented in which the economic incentives for the shipowners are of the same magnitude as the extra costs of the investment. In this case, the savings in infrastructure costs (icebreaker services) are similar to the extra costs for the shipowners, and the savings for the authorities can be transferred to the shipowners. The main characteristics of this new ice class are presented below in a table format:

Ice class definition	The ships operate independently in all ice conditions of the operating area
Requirement for ice conditions	The icebreaker is operational in the winter period for at least 3 months annually
Traffic density	At least one ship call daily
Impact on the shipowners	Waiting times for an icebreaker by ships eliminated, which leads to smaller stores; the ships have potential for Arctic operations
Impact on the Finnish Maritime Administration	Reduced icebreaker need and savings in fuel costs
Economic incentive	Reduced fairway dues and icebreaker status support
Advantage to society	Reduced need for icebreaker services and less icebreaker use

The definition of a new ice class is associated with several open questions. If there also are ships on the same route that need icebreaker escort, will any savings be created in the infrastructure costs, if an icebreaker must operate in the area? The cost calculation was very rough. For example, when calculating the icebreaker costs, it was assumed that one icebreaker is assisting on one route only. If the plans for a new ice class proceed, the first thing that is needed is more exact economic calculations.

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