STYRELSEN FÖR VINTERSJÖFARTSFORSKNING
TALVIMERENKULUN TUTKIMUSLAUTAKUNTA
WINTER NAVIGATION RESEARCH BOARD

External evaluation of the Finnish-Swedish Winter navigation R&I programme

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Final report

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Prelude

In the winter navigation research and operations collaboration, Finland and Sweden are taking on a wide range of common challenges in ice infested seaborn trade and regulatory framework in the northernmost parts of Europe. Achievements from the cooperation have also provided important knowledge and experiences, stimulating public and private operators, shipbuilders and users of maritime logistic resources towards more secure, cost efficient and climate smart solutions. Countries with icy winter conditions in the Baltic Sea as well as the connectivity of EU transport network benefits from progress made in winter navigation research.

The research and innovation cooperation through the Winter Navigation Research Board (WNRB) is based on a joint Swedish - Finnish agreement dating back to 1972. In order to take stock and report on developments the Finnish and Swedish maritime agencies, members of the WNRB and cooperation (Finnish Transport Infrastructure Agency, Finnish Transport and Communications Agency, Swedish Maritime Administration and the Swedish Transport Agency) have decided to evaluate 50 years of research and cooperation.

In their evaluation report, two external and independent evaluators, one from Finland and one from Sweden, have focused their assessment efforts on some main areas. These main areas include the overall governance, organisation and processes, research calls, research quality, research results and their societal impact and the relevance for winter navigation and operational icebreaking services. Furthermore, the evaluators assessed funding arrangements and long-term cooperation in demand driven winter navigation research. The WNRB also requested that the evaluation would present some recommendations on future development as well as the further strengthening of winter navigation research in the light of international developments.

The results of the evaluation will serve as a basis for addressing needs, shortcomings and how to build a more robust winter navigation research among transport authorities in Finland and Sweden for the coming 50 years.

We are proud to present an external evaluation that puts winter conditions, icebreaking operations and services in a research context, summing up 50 years of fruitful research cooperation between Finland and Sweden. Please find the anniversary report assigned by the WNRB.

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Abbreviations

AI	Artificial intelligence
AR	Augmented reality
CEF	Connecting Europe Facility, an EU funding instrument
CII	[vessels'] Carbon Intensity Indicator; IMO
ECB	European Central Bank
EEDI	IMO's Energy Efficiency Design Index (for newbuildings)
EEXI	IMO's Energy Efficiency Design Index (for existing vessels)
EUR	Euro
FIM	Finnish mark
FSICR	Finnish-Swedish Ice Class Rules
FoFin	A comprehensive research funding investigation in Sweden on-going in 2022-2024 (Forskningsfinansieringsutredningen)
FTA	Finnish Transport Agency (Liikennevirasto, Trafikverket; in operation from 2010 till the end of 2008)
FTIA	Finnish Transport Infrastructure Agency (Väylävirasto or Trafikledsverket), which has been operating since 1 January 2019
IoT	Internet of Things
IMO	International Maritime Organization
R&I	Research and Innovation
Ro-Ro	Roll on – roll off cargo vessels
Ro-Pax	Roll on – roll off vessels capable of carrying more than 12 passengers
SEK	Swedish krona
SMA	Swedish Maritime Administration (Sjöfartsverket)
STA	Swedish Transport Agency (Transportstyrelsen)
TEN-T	Trans-European Transport Network; EU's key policy for the development of coherent, efficient, multimodal, and high-quality transport infrastructure across the EU
Trafi	Finnish Transport Safety Agency (Liikenteen turvallisuusvirasto, Trafiksäkerhetsvärket; in operation from 2010 till the end of 2008)
Traficom	Finnish Transport and Communications Agency (Liikenne- ja viestintävirasto or Transport- och kommunikationsverket), from 1 Januray 2019 onwards
TRL	Technology Readiness Level(s)
UAV	Unmanned aerial vehicle
WINMOS I, II and III	Large projects under the name "Winter Navigation in Motorways of the Sea"
WNRB	Winter Navigation Research Board

1 Background

1.1 Nordic treaty on winter navigation

Far reaching and comprehensive cooperation in several societal areas between the Nordic countries have deep roots. For example, passport freedom between the Nordics entered into force already in 1952. Formal integration took further steps, for example, with The Helsinki Treaty – Agreement on Co-operation between Denmark, Finland, Iceland, Norway and Sweden. It was signed on 23 March 1962 and took effect on 1 July of that year[1].

One specific area of cooperation, especially important to the Nordic countries and for Finland and Sweden in particular, has been a solid platform to foster joint actions, Research and Innovation (R&I), deployment, usage, and benefits in the field of winter navigation. Still in the 1960s, many ports closed when water froze, fresh goods were redirected to rail/road and goods that lasted over the winter were stockpiled in the ports. With growing volumes, industry (demands and production), populations and the logistical cost of storing and capital tie-up, demands on ports, operational also during wintertime, were step by step increased.

To meet these requirements, an “Agreement between Finland, Denmark, Norway and Sweden concerning co-operation in ice-breaking” was signed in Helsinki on 20 December 1961[2]. This Agreement was followed by a bilateral treaty[3] between Finland and Sweden, signed in Reykjavik on 29 August 2011, which came into force in January 2013.

Following the 1961 Nordic Agreement on cooperation in icebreaking, Finland and Sweden established a joint platform to support research on winter navigation. With a bilateral agreement between the two countries, the Winter Navigation Research Board (WNRB) was established. It held its first conference (“Havsiskonferens”) in Stockholm on 3-4 October 1972, and its results are documented in the first report published by the WNRB, or *Styrelsen för Vintersjöfartsforskning* in Swedish and *Talvimerenkulun tutkimuslautakunta* in Finnish.

As of 1972, this cooperation, procurement and commissioning of icebreakers in the Baltic Sea and an increasingly fruitful cooperation between primarily Finland and Sweden has kept ports open, enabling shipping companies and ports to meet growing logistic demands and volumes, thereby creating growth and prosperity for the people in Finland and Sweden.

1.2 The 1972 governmental agreement on winter navigation research

In 1972, the Director Generals of the Finnish Maritime Administration and the Swedish Maritime Administration signed an agreement on research cooperation, primarily related to technical conditions for winter navigation, named the Finnish-Swedish Winter Navigation Research programme (WNRB). The Board has since then issued Calls for proposals every year, with a particular focus on need-based winter navigation Research and Innovation (R&I).

[1] The original text has been amended by Agreements that were signed on 13 February 1971, 11 March 1974, 15 June 1983, 6 May 1985, 21 August 1991, 18 March 1993, and 29 September 1995. The most recent amendments entered into force on January 2nd, 1996.

[2] The original Agreement is available in Finnish here.

[3] “Avtal mellan Konungariket Sveriges regering och Republiken Finlands regering om gemensam organisering och samarbete i fråga om service till vintersjöfarten”; available here.

In 2023, WNRB consists of representatives from the Finnish Transport Infrastructure Agency (FTIA), the Finnish Transport and Communications Agency (Traficom) and the Swedish Maritime Administration (SMA) in association with the Swedish Transport Agency (STA). Traficom of Finland is hosting the secretariat for the WNRB, managing the annual Call and, in cooperation with the other representatives, the assessment and approval process.

The Finnish and Swedish government agencies participating in the WNRB have a responsibility for continuous development and renewal of winter navigation management and operations. The emphasis is on the Baltic Sea and Gulf of Bothnia in particular.

1.3 Bilateral Finnish-Swedish agreement on icebreaking cooperation signed in 2012

The aim of the agreement is to improve the availability of icebreakers and reduce waiting times and costs. The agreement deepens cooperation between Finland and Sweden in the planning and organisation of winter shipping services. In this way, even during difficult winters, more efficient and economical icebreaking services are secured.

The agreement enables savings, as the closest breaker will assist ships regardless of their destination port. Because of this, the empty displacements of breakers and the resulting fuel costs and expectations are reduced. In the long term, the total costs of breaking ice in the contract area will be reduced, when the parties do not have to reserve equipment alone and independently to cope with the worst ice situations.

The contract is valid for 20 years until year 2032. The agreement requires Finland to have the capacity of five icebreakers. Four of these should be so-called Class A icebreakers and one Class B icebreaker. Both Finland and Sweden have the icebreakers required by the agreement.

Cooperation has been carried out primarily in the Gulf of Bothnia, but during difficult ice winters also in the entire Baltic Sea basin to assist traffic to Finland or Sweden. The principles of the cooperation are as follows:

- Both reserve required icebreaking capacity
- Common management of the operations and assigning assistance via IBnet[4]
- Common principles of setting restrictions and issuing dispenses based on HELCOM recommendations
- Common prioritization of winter navigation assistance
- Cost sharing principles

1.4 The context of winter navigation in view of this evaluation

Now that WNRB cooperation has passed its 50th anniversary, it is an opportune moment to look back at its achievements. These have served the core needs of both the public and the private sector engaged in winter navigation primarily in Finland and Sweden, but have been deployed much wider than that.

Perhaps the most important global impact of WNRB has been the continuous development of the Finnish-Swedish Ice Class Rules (FSICR) for merchant vessels. The ice classes from the highest to the lowest are: IA

[4] The Finnish-Swedish icebreaking information system IBNet contains information about the weather, ice conditions and traffic situation, and transmits the information between the different connected units (icebreakers, coordination centres, VTS etc.).

Super, IA, IB, IC, II and III (see **Table 1**). A vessel's ice class is verified by a classification agency according to the detailed technical requirements laid out in FSICR (on these, see e.g. SMA).

Table 1 A simplified interpretation of ice classes of merchant vessels according to the Finnish-Swedish Ice Class Rules. Source: SMA 2022 and Traficom

Note that a IA Super vessel is not supposed to manage solid ice over 100 cm **on its own**, but is capable of operating in an existing ice channel, where the ice thickness is 100 cm, and which may be covered with 10 cm of newly frozen ice.

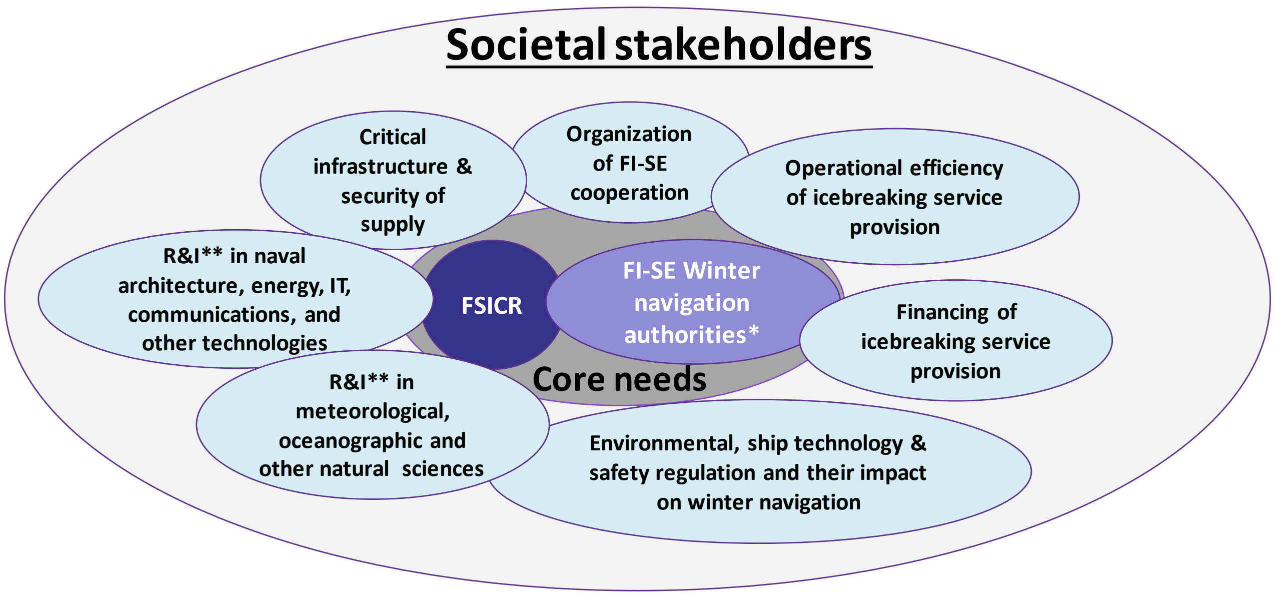
Ice class	For traffic in	Ice thickness*	Thickness of ice channel**	Polar Class equivalent***
IA Super	Extreme ice conditions	> 100 cm	100 cm + 10 cm of ice layer frozen overnight	PC6
IA	Difficult ice conditions	> 50 cm	100 cm	PC7
IB	Moderate ice conditions	30 – 50 cm	80 cm	
IC	Light ice conditions	15 – 30 cm	60 cm	
II	Very light ice conditions	10 – 15 cm		

*) The thickness of smooth ice when sizing the ship's structures; not related to vessel performance

**) The condition in which the vessel must reach a speed of 5 knots; is used to determine the statutory minimum engine power of the vessel

***) Under certain conditions; Polar Class is defined by IMO

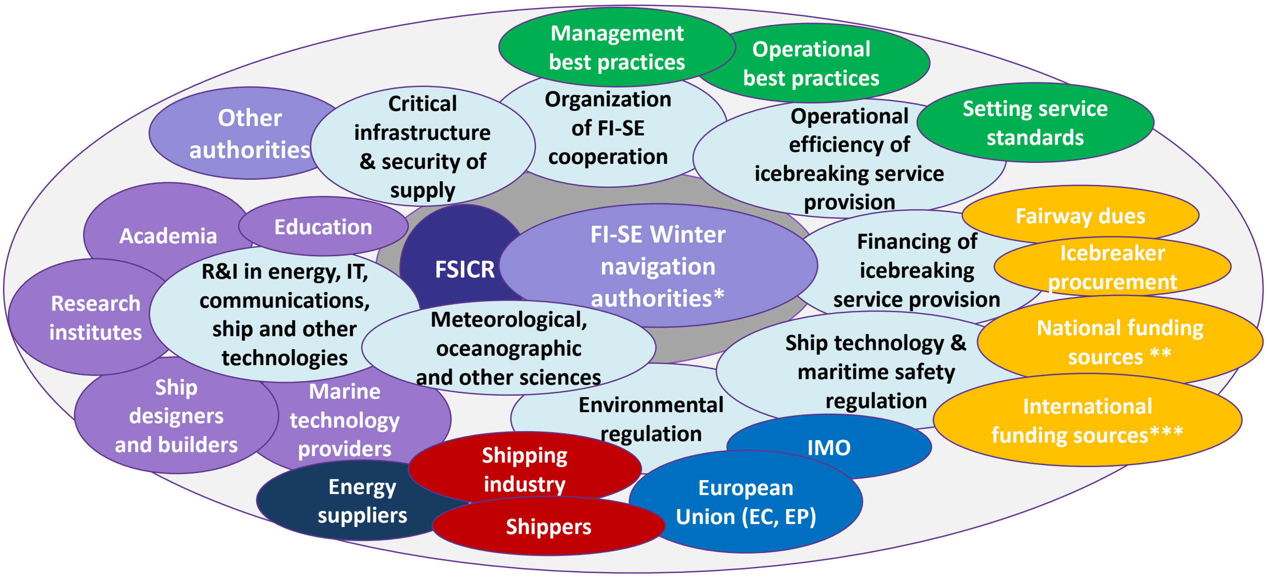
FSICR is today a global "industry standard", development of which has been closely linked to WNRB funded projects. In addition, a wide spectrum of government agencies and industry bodies from shipping to shipbuilding and classification societies around the world use results from the WNRB work, such as the FSICR, in their operations. These include the IMO and the EU.



*) Including the procedures and level of available funding when deciding on WNRB research grants
**) R&I = Research and Innovation

Figure 1 Simplified illustration of the key affected spheres that have benefited from research funded by WNRB

Figure 1 provides a simplified illustration of the key spheres linked to research funded by WNRB. It goes without saying that also the government as a whole and the sector Ministries under which the Finnish and Swedish winter navigation authorities are organised are also among the beneficiaries.



***) Including the procedures and level of available funding when deciding on WNRB research grants**
****) The authorities direct funding complemented by e.g. Vinnova & Business Finland and**
*****) Incl. EU's Connecting Europe Facility and Military Mobility instrument**

Figure 2 Simplified illustration of the broader set of societal stakeholders or sectors that have benefited from research funded by WNRB

In a wider context, several societal stakeholders and sectors have benefited from WNRB research too. These are outlined in **Figure 2**. Shipping companies operating in ice-infested waters as well as shipbuilders and designers working with icebreakers of ice-classed vessels are the most direct beneficiaries.

This is accentuated especially when the outcome of political processes leads to investments in new icebreakers, as is now the case in Sweden. The decision to order two new icebreakers[5] was made in December 2022 (with an option for a third one).

The Swedish government has granted SEK 3.4 billion (about €285 million in exchange rate of September 2023) for the Swedish Maritime Administration (SMA) in its 2023 budget for the construction of two icebreakers. The first vessel is planned to be delivered in the winter 2026/2027 and the second about a year later.

This substantial investment was successfully linked to WINMOS III project (2023-2027) led by SMA, which has a budget of €186.9 million. €60 million of this was funded by EU's Connecting Europe Facility in summer 2023. The majority of WINMOS III funds will be used in connection to the new Swedish icebreaker to be completed in 2027. WINMOS is the abbreviation of "Winter Navigation in Motorways of the Sea".

[5] An outline of their environmental, operational and technical specifications: see, for example, Aker Arctic 2023.

Sweden is also planning to apply for financial assistance for its second new icebreaker from EU's new Military Mobility programme. Its next application expires on Sept. 21, 2023, where a total of €790 million will be distributed.

In Finland, the need to reform the organisation of icebreaking and renew parts of the icebreaker fleet is also manifested in the new government's programme for years 2023-2027 as follows:

> *"The operating conditions for winter navigation will be ensured. The way icebreaking is organised will be reformed and a long-term programme for the replacement of icebreakers will be launched during the government term."*
> *(Programme of Prime Minister Petteri Orpo's Government, 20 June 2023)*

1.5 Scope of the present evaluation

The present evaluation, which was initiated and funded by the Finnish and Swedish authority partners in the WNRB, covers the following areas:

1. **Governance, management, and funding**
    a. The WNRB and the 1972 agreement.
    b. Funding, structure, processes, and project funding decisions
    c. The WNRB timeline, process and criteria for Calls, quality assurance and decisions.

2. **Results and impacts**
    a. Evaluation of the quality and impact assessments in the WNRB process.
    b. Research reports, and an assessment of their impact and contribution to operational icebreaker services, transport policy goals, and further development of regional and international work on regulations, directives, and standards.

3. **Analysis and considerations**

4. **Conclusion and recommendations**

In addition, Chapter 2 and partly also Chapter 5.3 of this report provide a short background of winter navigation and icebreaking conditions in Finland and Sweden, and presents also the nature and volume of these operations.

2 Introduction to icebreaking needs and operations in Finland and Sweden

This section gives a short introduction to the scope, location and length of icebreaker periods in the Baltic Sea, which can be helpful for readers that are not familiar with the topic.

2.1 Ice coverage in the Baltic Sea and corresponding icebreaking needs

The operational area for Finnish icebreakers comprises both the Gulf of Bothnia[6], Archipelago Sea between Åland Islands and mainland Finland and the Gulf of Finland, and the Sea of Åland, which is between Åland and Sweden. For Sweden, the needs are mainly in the Bay of Bothnia but also in the big Swedish lakes. During severe winters icebreaking may also be needed along the Swedish coast south of Bay of Bothnia.

During a rather typical ice winter 2021, for example, the sailing distance from ice edge during maximum ice extension to the northernmost ports in Bay of Bothnia was about 200 NM, and about 100 NM in ice thicker than 15 cm (**Figure 3**).

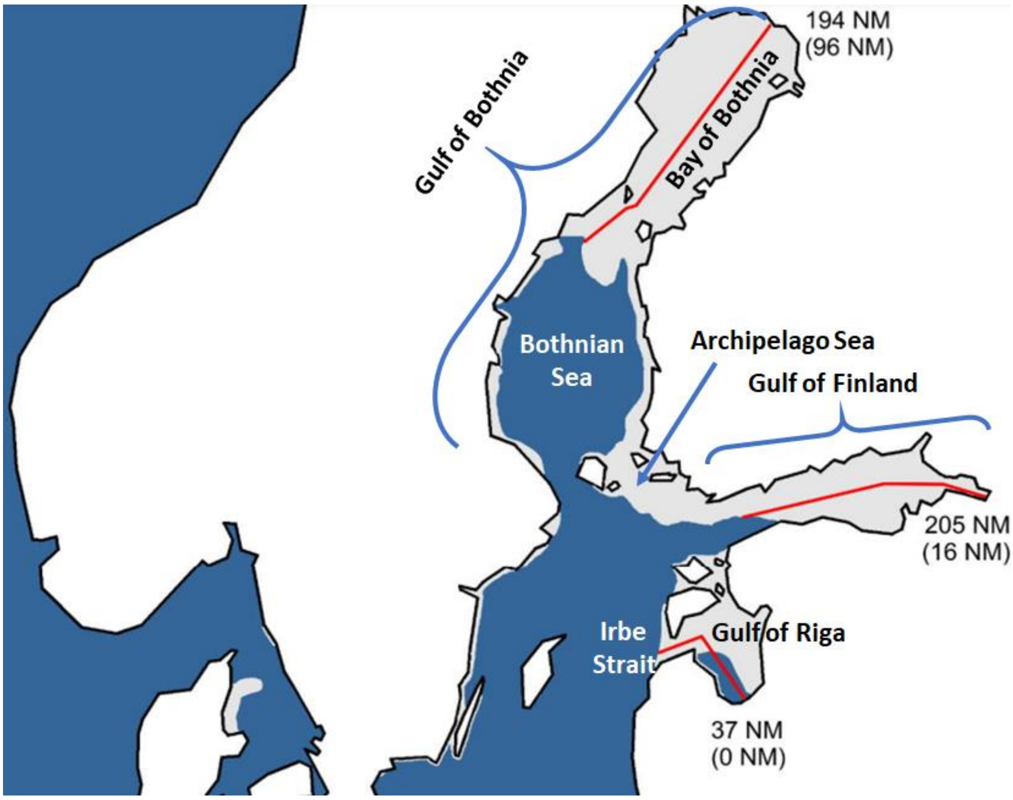


***Figure 3** Selected sailing distances in nautical miles (NM) from ice edge during maximum ice extension on 15th of February 2021, which as an average ice year. The figures in parenthesis refer to ice over 15 cm thick. Based on: Finnish Meteorological Institute, data available here*

Annual variations in the ice coverage can be very large. Since 2003, the widest coverage in the Baltic Sea (309,000 km^2) occurred in 2010-2011, when the sailing distance to Riga was 206 NM and 565 NM to Kemi from ice edge during maximum ice extension. The smallest recent ice coverage (37,000 km^2) was in 2019-2020, when there was ice only in the Bay of Bothnia. (**Figure 4**)

[6] The Gulf of Bothnia (Pohjanlahti, Bottniska viken) is divided into i) the Bay of Bothnia (Perämeri, Bottenviken) roughly north of Vaasa and ii) Bothnian Sea (Selkämeri, Bottenhavet) south of Vaasa to the Åland Islands.

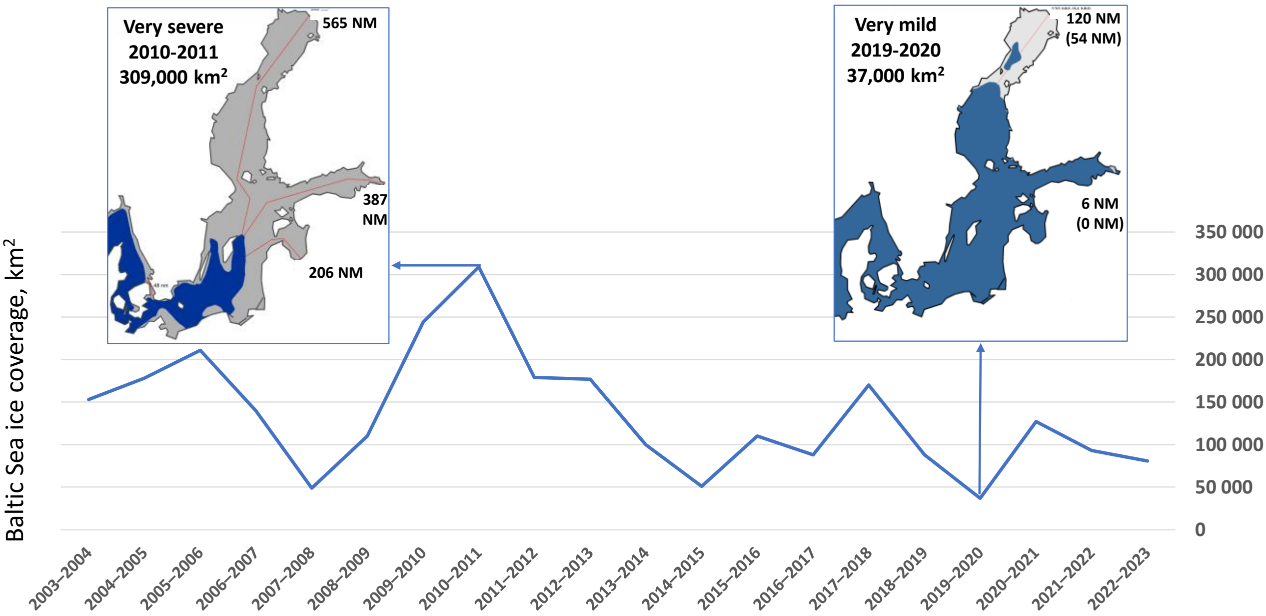


Figure 4 ***The Baltic Sea ice coverage in 2003 – 2023 in km², and maps for the mildest and the most severe ice years during this period. Selected sailing distances in nautical miles from ice edge during maximum ice extension. The figures in parenthesis refer to ice over 15 cm thick. Based on: Finnish Meteorological Institute, see [here](#).***

Usually, over 80% of all operational days and the number of assistances of Finnish icebreakers take place in the Bay of Bothnia. Swedish icebreakers operate mostly in the Gulf of Bothnia, and almost exclusively in the Bay of Bothnia. Only during the most severe winters, some icebreaking assistance may be needed also in some other regions along the Swedish coastline and the big lakes. This is illustrated in Figure 5 for the period 1996-2012, where the large variations depend on the severity and length of ice winters.

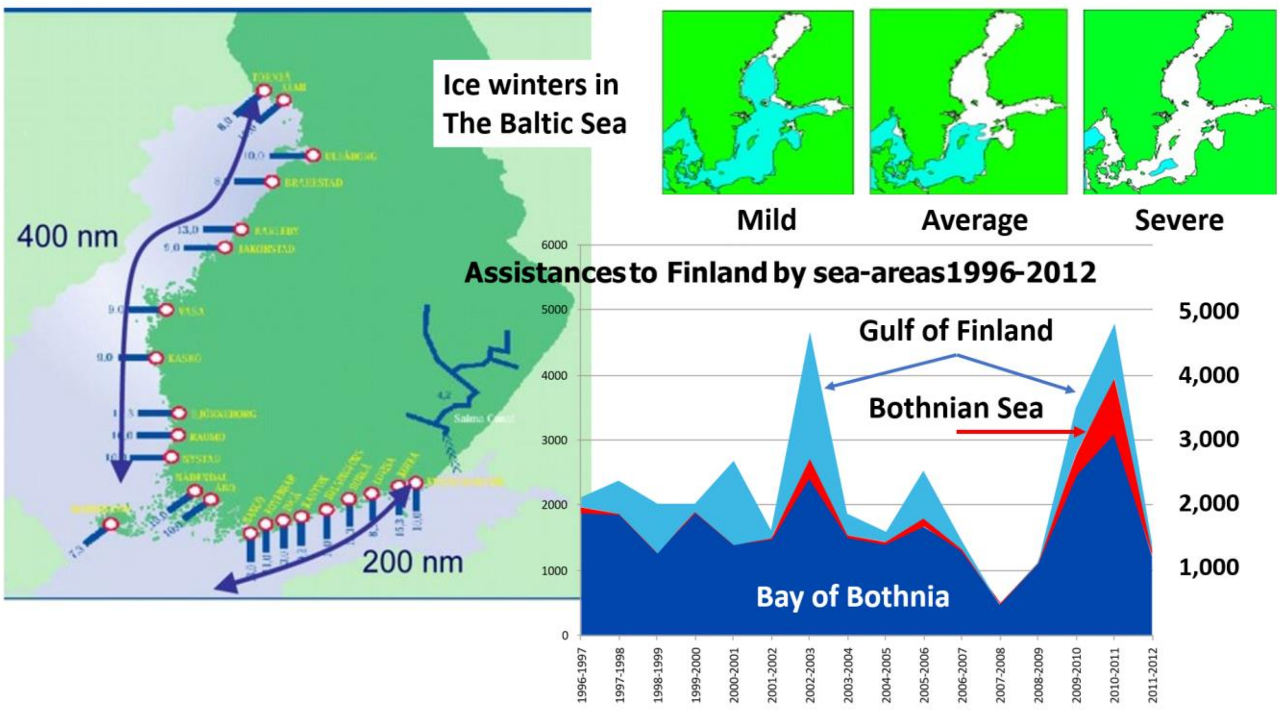


Figure 5 ***Icebreaker assistances to Finnish ports by sea area in 1996-2012. Source: FTIA***

The volume of service events depends greatly on vessel traffic volume, length of fairways and routes to be assisted and the severity and length of ice conditions during the winter (**Figure 6**).

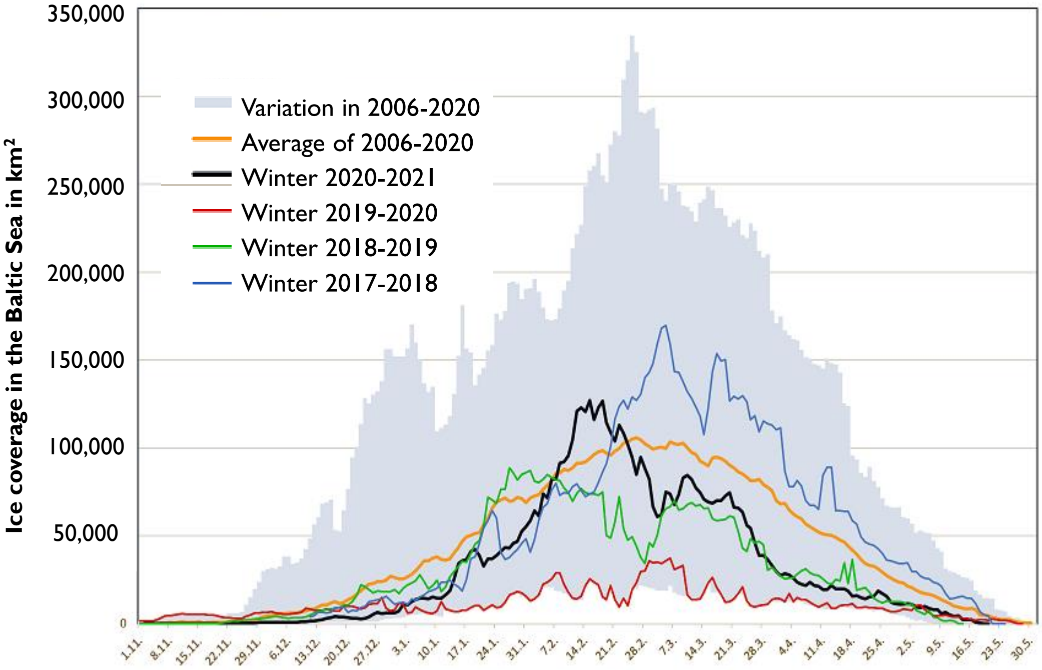


***Figure 6** The extent of ice coverage in the Baltic Sea during recent winter periods in km^2.*
Source: Finnish Transport Infrastructure Administration (FTIA) 2021

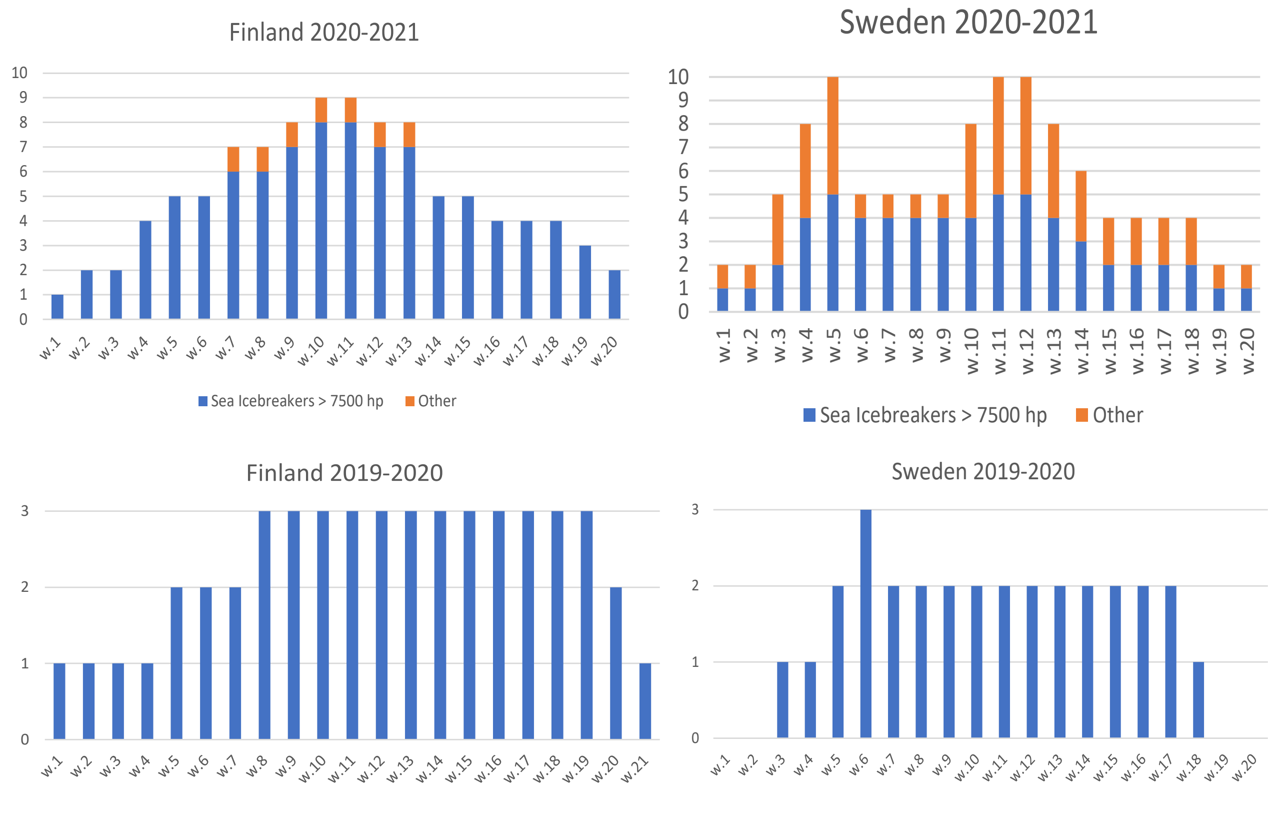


***Figure 7** The number of icebreakers engaged in Finland and Sweden during the seasons 2019-2020 and 2020-2021. "Other" refers to Service Operation Vessels, such as large seagoing tugboats with icebreaking capability. Source: BIM 2020 and 2021 (Baltic Ice Management reports found here)*

The variation in the severity of the winter is naturally reflected in the number of icebreakers engaged, which is illustrated in **Figure 7**. It shows that in a "normal" period as in 2020-2021, Sweden and Finland engaged up to 9 or 10 icebreakers during the peak weeks, and the duration of the entire icebreaking period was 20 weeks in both countries.

During a mild winter period 2019-2020, both Finland and Sweden had to assign only three icebreakers; Finland for consecutive 12 weeks, but Sweden only during one week. The entire icebreaking period lasted for 21 weeks in Finland and 16 weeks in Sweden.

2.2 Key performance indicators (KPIs) of icebreaking assistance

The three Key performance indicators (KPIs) of icebreaking assistance are as follows:

- Average waiting time on icebreaker assistance
- Availability (open ports)
- Availability (ship received assistance without waiting time)

It is important to note that the average waiting time KPI is calculated only for those vessels that are actually assisted. During a mild winter, most vessels manage to sail without having to wait, mainly due to shorter assistance distances.

KPI on average waiting time on icebreaker assistance in Finland and Sweden is max. 4 hours. Also the KPI on ship receiving assistance without waiting time is set at 90% both in Finland and Sweden, due to cooperation between Finland and Sweden.

2.2.1 Finland

In Finland, the average waiting time for icebreaking assistance was 3.7 hours in 2022, which increased slightly from the previous year's winter due to the challenging conditions, so the 4.0 h target required by the service level promise was achieved. The completion rate of vessels that were assisted within the target (max. 4.0 h waiting time) remained at the level of the previous year, at 95.5%. The target (90%) was exceeded.

Although winter period 2021/2022 was regarded as mild, it was challenging for icebreaking operations e.g. due to packed ice. In addition, the Finnish big icebreakers had quite a few technical problems, some of which were long-lasting.

During a difficult ice winter, such as in 2010-2011, the vessels' average waiting time for icebreaker assistance in Finland was 12.6 hours, and about 85% of vessels could pass without any waiting.

Operational icebreaking assistance days overseen by FTIA were 888 in 2022 (710 in 2021 and 325 in 2020). Of these, 177 days were performed in 2022 by other service providers than the state-owned Arctia Icebreaking Ltd.; in 2021 that number was 83 and in 2020 only 3.

Arctia Icebreaking Ltd. performed almost 2,100 icebreaking assistances in 2022 in Finland, while the number was about 1,500 in 2021, 700 in 2020, and about 1,700 in 2019. Seven of its eight icebreakers had 627 operational icebreaking days in 2021, while the number was 322 days in 2020 and 547 days in 2019, respectively, which reflects the large variation in the severity of winters (Arctia 2022).

In addition to Arctia Icebreaking Ltd., FTIA has also a contract with Alfons Håkans Ltd., which is a provider of seagoing tugs. For example, it's tugboat Zeus of Finland has occasionally been used in the Gulf of Finland.

2.2.2 Sweden

SMA's three KPIs for icebreaking are shown in **Table 2**. KPI on average waiting time on icebreaker assistance is max. 4 hours, which is the same value used also in Finland. Also the KPI on ship receiving assistance without waiting time is set at 90% both in Sweden and Finland.

Table 2 ***Key performance indicators (KPIs) for icebreaking in Sweden in 2020-2022. Source: Swedish Maritime Administration annual report for 2022***

	Target	Achieved in 2022	2021	2020
Average waiting time on icebreaker assistance	Max. 4 hours	2 h 54 min.	2 h 24 min.	2 h 36 min.
Availability (open ports)	100 %	99.9 %	99.9 %	100 %
Availability (ship received assistance without waiting time)	90 %	98.4 %	99.0 %	99.4 %

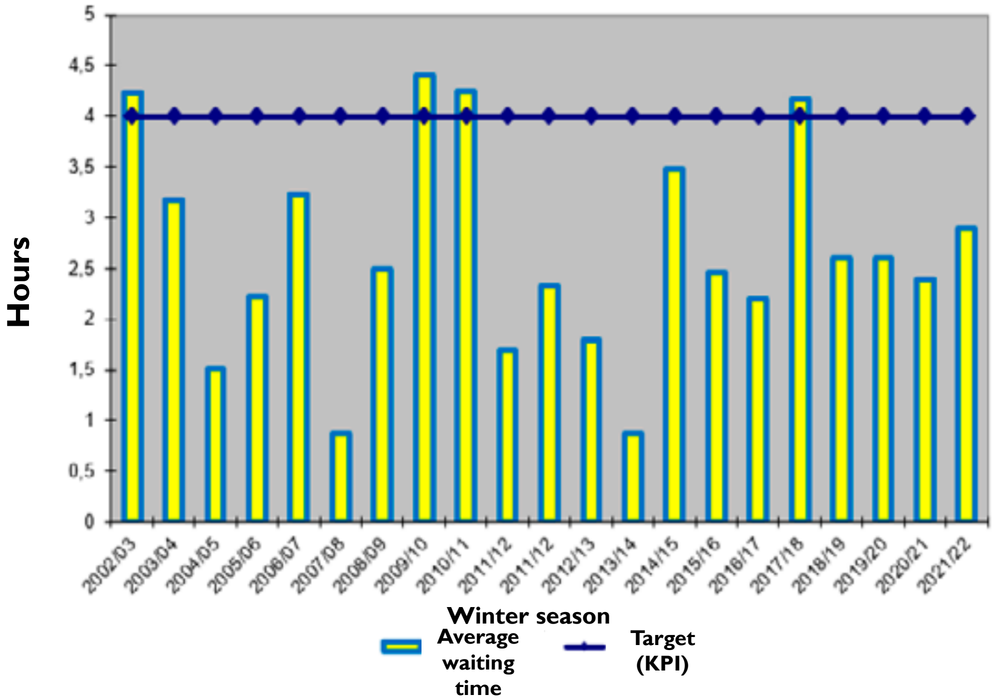


Figure 8 ***Average waiting time to Swedish ports 2003-2022.***
Source: A summary of the ice season and icebreaking activities 2021/2022, [SMA](#) 2022

Since 2002, the average waiting time in Sweden has been slightly above the 4 hour KPI only four times, as shown in ***Figure 8***.

2.3 Cost of icebreaking in Finland and Sweden

2.3.1 Finland

Table 3 provides some financial data on Finnish icebreaking operations. Since 2015, the actual costs for icebreaking services in Finland have been between €40 million to €65 million per year, which reflects the changing ice conditions.

The corresponding income in the state budget intended to cover these costs is the income from fairway dues, which are collected by Finnish Customs, subordinated to the Ministry of Finance. Fairway due income has lately been approximately €45 million per year. In Finland, vessels ice class (FSICR) has a significant impact on the level of the cost (see **Table 4**), whereas vessels emission is an important criterion in Sweden.

Table 3 ***Income and expenses of activities covered by fairway dues in Finland, € million. Source: State budgets for 2020-2024 and FTIA financial statements for 2021 and 2022***

	2020	2021	2022 (Target)	2022 (Actual)	2023 (Budget)	2024 (Estimate)
Revenues						
Fairway due revenue	46,7	44,7	47,8	51,7	45,0	51,0
Other income	1,6	0,8	0,3	0,9		
Total income	**48,3**	**45,5**	**48,1**	**52,6**		
Total cost						
Total separate costs (incl. icebreaking)	74,3	92,9	84,0	103,8		
Share of total joint costs	15,1	4,3	4,7	5,0		
Total costs as a whole	89,4	97,2	93,7	108,8		
Surplus (+) / Deficit (-)	-41,1	-51,7	-45,6	-56,2		
Cost coverage of all activities under Fairway Due Act	**54 %**	**47 %**	**51 %**	**48 %**		
State budget allowance for icebreaking services to FTIA	*64,0*	*62,0*	*60,0*	*n.a.*		
Fairway dues % of allowance for icebreaking in the state budget	*75 %*	*73 %*	*80 %*	*n.a.*		

A more detailed cost structure is not available from open sources, except for fuel costs. In 2022, icebreakers fuel costs paid by FTIA were about €12.9 million, which was about €5.7 million higher than in 2021, and about €10.1 million higher than in 2021. The large variations are mainly due to differences in the severity of ice winters in addition to changes of fuel prices.

About 75% to 80% of Finland’s icebreaking costs can be covered with fairway due revenue, but also other fairway maintenance tasks are covered with these revenues. When these other tasks are accounted for, the cost coverage varies from 45% to 55%.

Before 2015, annual fairway due revenue was €80 million to €90 million. The significant drop in 2015 was due to the government decision to compensate for the anticipated rise in shipping costs, when IMO’s new sulphur emission rules (SECA) became effective in the Baltic Sea. Since 2015, the lower level has been maintained with temporary legislation, but the new government announced in August 2023 that this lower level will be permanent as from 2025.

Table 4 Unit prices for Finnish fairway dues as from 1 January 2015 (valid also in 2023)[7]. Source: Finnish Customs

Ice class	Cargo ship Unit price (euros)	Passenger ship Unit price (euros)
1A Super	0,470	0,625
1A	1,098	1,294
1B, 1C	2,578	2,358
II, III	4,381	4,169

Finnish icebreakers are owned and operated by state-owned Arctia Oy (Ltd.), or more specifically by its subsidiary Arctia Icebreaking Oy (Ltd.). Its eight icebreakers are the primary assets to provide icebreaking services in Finnish waters. Arctia's icebreakers are contracted by FTIA for winter periods with funds it receives from state budget. FTIA also has the oversight of icebreaking management, which is done in close co-operation with its Swedish counterpart SMA. (Arctia Icebreaking Oy's financial figures, see **Table 5**)

Table 5 Income statement figures of Arctia Icebreaking Oy, the icebreaking subsidiary in Arctia Oy. The unit is thousand euros. Source: Finder.fi

Arctia Icebreaking Oy	2022	2021	2020	2019
Turnover ('000 €)	47 467	43 998	43 258	43 603
Change of turnover in %	7,9 %	1,7 %	-0,8 %	-3,1 %
Operating margin in %	33,3 %	36,4 %	35,2 %	32,7 %
Operating profit ('000 €)	2 403	2 903	8 402	7 482
Operating profit in %	5,1 %	6,6 %	19,0 %	17,2 %
Result for the financial year ('000 €)	37	2 382	1 959	14
Personnel	206	191	180	173

Arctia Oy's business operations are divided into three operative areas: 1) icebreaking, 2) fairway maintenance and 3) hydrographic surveying. The two latter ones were incorporated into Arctia in 2019, when another state-owned company Meritaito Oy merged with Arctia Oy. The turnover of the whole Arctia concern was €80.2 million in 2022, and €71.2 million in 2021, so the share of icebreaking from the overall turnover is about 60%.

Arctia Oy is a non-listed commercial company wholly owned by the state, and it is overseen by the Ownership Steering Department of the Prime Minister's Office. However, it is not entrusted with special state assignments, unlike, for example, pilotage company Finnpilot Pilotage Oy or Traffic Management Finland Oy, which manages road, rail and shipping (VTS) traffic.

[7] The unit price of a cruise ship is 0.911 euros, that of a high-velocity vessel is 5.381 euros, and the unit price of a ship running without a transport machinery of its own is 2.107 euros. Fairway dues for passenger ships and high-velocity vessels are paid for the first 30 port calls made during a single calendar year. For cargo ships, fairway dues must be paid for the first 10 port calls made during a calendar year. In Sweden, fairway dues are based on monthly visits.

Arctia Oy's Board has currently six members, who are nominated by the Prime Minister's Office. One of the Members represents the Ownership Steering Department, while the other five are experienced business professionals and come from commercial and/or other state-owned firms. As a state-owned company, Arctia is also subject to governance and Corporate Responsibility auditing done by the National Audit Office of Finland.

2.3.2 Sweden

SMA owns and operates the five Swedish icebreakers, which are used within the Baltic Sea. IB Oden is occasionally chartered out for scientific missions outside the winter period. The development of Swedish icebreaking costs and the amount of costs that are connected to fairway due income are shown in **Figure 9**.

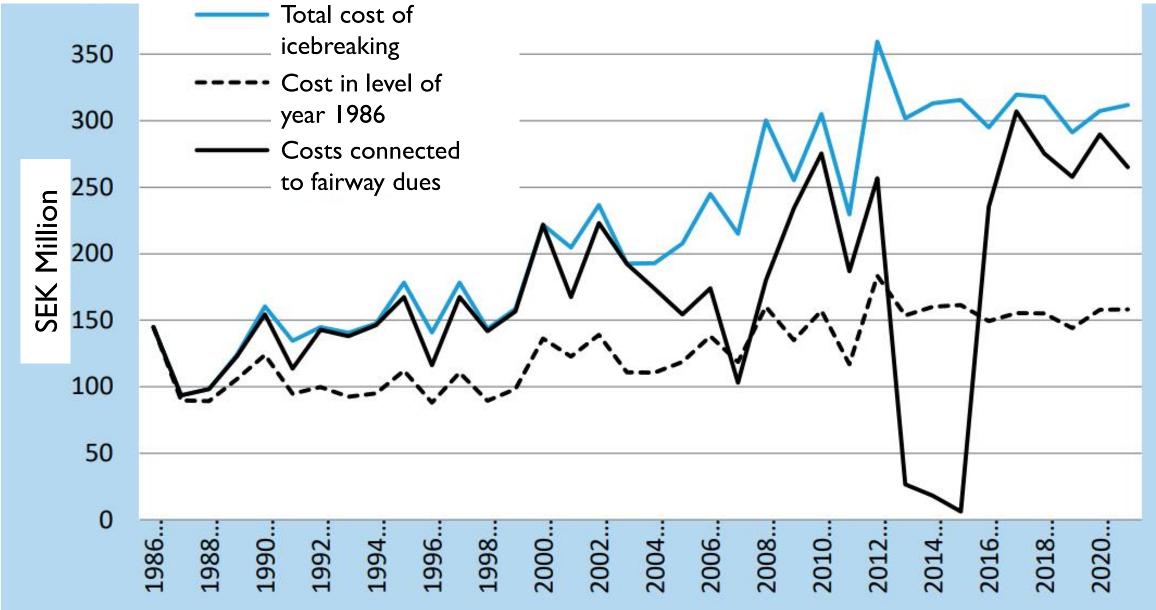


Figure 9 Icebreaking costs in Sweden from winter period 1986/1987 till 2020/2021.
Source: A summary of the ice season and icebreaking activities 2021/2022, SMA 2022

In Sweden, fairway due income for 2023 is expected to reach about €100 million, while costs for icebreaking services are between €20 million to €40 million. Thus, all of Sweden's icebreaking costs can be covered by fairway dues collected from commercial shipping in international traffic. (SMA 2022).

More detailed cost structure of Swedish icebreaking operations can be found in **Appendix 6**.

3 Winter Navigation Research Board governance and processes

3.1 Governance of the Winter Navigation Research Board

Throughout its existence, the management structure of the WNRB has remained by and large the same, where the Swedish and Finnish transport and maritime administrations and their winter navigation experts have been responsible for its operation.

WNRB has managed the research cooperation, including the assessment of submitted project proposals to annual research Calls, and formulated funding recommendations. This has been a non-bureaucratic and cost-efficient approach, which has managed to maximise value for money and usability for WNRB partners.

Initially, the main stakeholders were the Swedish and Finnish Maritime Administrations[8]. Since 1972, the administrative structure has evolved in Finland in such a way that the winter navigation activities of the Finnish Maritime Administration were split into the Finnish Transport Agency (FTA, Liikennevirasto, Trafikverket) and the Finnish Transport Safety Agency (Trafi), in 2010. Subsequently, the main part of the FTA – including the winter navigation management - was transformed into Finnish Transport Infrastructure Agency (FTIA; Väylävirasto or Trafikledsverket) as from 1 January 2019. At the same time TraFi was merged with the Finnish Communications Regulatory Authority and parts of the FTA and this new agency became the Finnish Transport and Communications Agency, Traficom.

The formation of Swedish Transport Agency (STA, Transportstyrelsen[9]) in 2009 brought earlier, somewhat scattered transport issues, such as regulations, permits, registration and follow-up, for road, rail, aviation, and shipping together in one agency, fostering synergies and cutting cost.

In 2023, the four participating agencies in the WNRB are:

a) Finnish Transport and Communications Agency (Traficom), under the Ministry of Transport and Communications in Finland

b) Finnish Transport Infrastructure Agency (FTIA), under the Ministry of Transport and Communications in Finland

c) Swedish Maritime Administration (SMA, Sjöfartsverket), under the Ministry of Rural Affairs and Infrastructure in Sweden

d) Swedish Transport Agency (STA, Transportstyrelsen), under the Ministry of Rural Affairs and Infrastructure in Sweden

In the WNRB research cooperation, the participating agencies have managed to create a high-quality process with a minimum of administrative overhead, with good to very good project quality and industrial relevance ensuring high yield for public resources into the funded projects.

Over the years, the constructive and efficient attitude of the agencies has also contributed to attract projects, researchers, co-funding, and partners to the winter navigation field, and funded highly relevant and “value for money” projects.

[8] From 1917 till 1998, the Finnish Maritime Administration operated under the name Merenkulkuhallitus or Sjöfartsstyrelsen, and thereafter till the end of 2009 as Merenkulkulaitos or Sjöfartsverket

[9] https://www.transportstyrelsen.se/en/About-us/

3.2 Funding procedure within the Winter Navigation Research Board

The WNRB research cooperation has been funded up to 50% by Finland and up to 50% by Sweden since year 1972. The funding procedure is explained below and illustrated in **Figure 10**.

In Finland, the mandate to take funding decisions is given to Traficom and FTIA, both of which have a 50% share of the Finnish funding, i.e. 25% each of the total funding.

In Sweden, SMA had the funding and took funding decisions until 2013 when the funding and mandate was transferred to Trafikverket. SMA kept its role as a participating partner in the WNRB. SMA is responsible for maritime security and accessibility as well as building, funding, operating and maintaining all maritime relevant infrastructure.

As from year 2014, the Swedish decisions on WNRB funding are taken by the Swedish Transport Administration (Trafikverket), based on proposals from the WNRB and SMA.

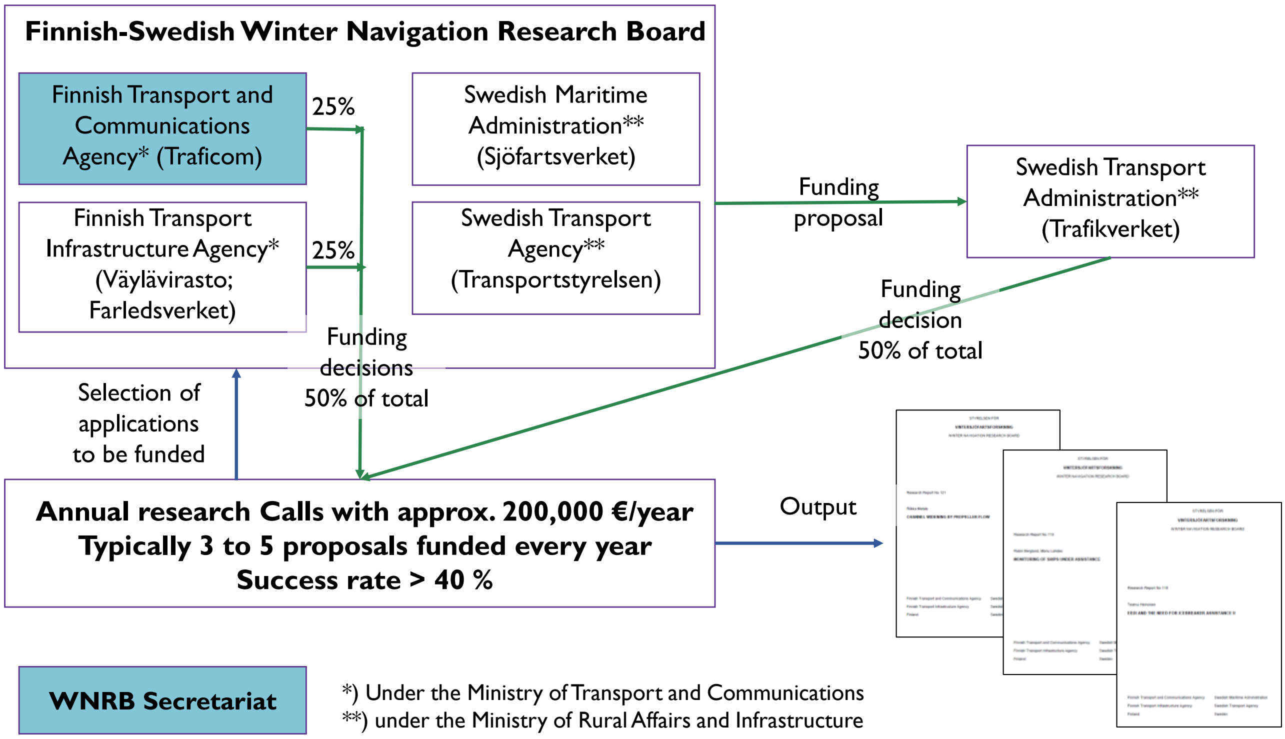


Figure 10 Funding procedure of the Winter Navigation Research Board. The three contractual partners in WNRB funding are Traficom and FTIA from Finland and Swedish Transport Administration

The Swedish Transport Administration (Trafikverket) was formed in 2010, which brought several agencies with responsibility for road, rail, aviation and maritime transport together into one organisation. This new organisation was also given the overall responsibility for strategic planning in all transport areas, including R&I (forskning och innovation, FoI) programmes and funding[10]. In this reorganisation of transport sector administration, some agencies, such as SMA (Sjöfartsverket), were kept as separate authorities.

[10] For a recent comprehensive overview of Swedish R&I in freight transport, see Trafikanalys (2022)

In 2023, Swedish Transport Administration has the maritime R&I responsibility, which is managed within a so-called maritime research portfolio[11]. This portfolio is also responsible for the funding of WNRB projects.

The Swedish Transport Administration's R&I budget for 2022-2033 is approximately €563 million[12] and the annual budget for maritime-related R&I in 2022 was approximately €10 million. The annual Swedish WNRB funding commitment is €100,000, or about 1% of this annual maritime R&I budget.

The Swedish agencies in the WNRB can only recommend decisions, since neither of them has the mandate to take funding decisions. Recommendations are sent to Swedish Transport Administration (Trafikverket), where they are assessed and decided within its maritime portfolio. Upon a positive decision, Swedish Transport Administration is the Swedish contractual partner with the funded research project.

An advantage with this centralised model is that enough resources are available to manage large and long-term R&I programmes. This applies especially to big rail and road transport programmes and projects. Staff is in one organisational place, which enables to build critical mass, create and maintain networks, and provides ability to influence politics, policies and priorities. Overall, this has worked very well.

A disadvantage for smaller programmes, such as the WNRB, is that the priority of such smaller programmes or projects is usually low. At the same time, the advantage with the centralised model is easily lost.

Another important *disadvantage* is that the important cooperation with the agency with experience, contact, staff and co-operations (here: SMA), is dwarfed as an actor, funder, partner and influencer, when it has no mandate to take funding decisions in R&I projects.

SMA manages several large and small R&I projects not directly related to the WNRB cooperation, primarily with external funding. These projects have encouraged SMAs R&I to join, as a responsible agency, primarily not for co-funding but rather for the agency's long and high-quality experiences within the maritime field. This is positive and has maintained a fruitful and strong cooperation with these projects and their partners. SMA is thereby taking responsibility for the maritime operation in accordance with the regulation[13] decided by the government.

This further underlines the somewhat strange governance structure for funding maritime projects in general and, given the scope of this investigation, the WNRB cooperation in particular.

3.2.1 Funding decisions made by the WNRB in 2004 and 2008-2021

Figure 11 summarises funding of WNRB projects in 2004 and 2008-2021. It shows the total and average amount awarded per project in € per year[14]. Since 2017, typically 4 to 5 projects per year have been approved (4 to 6 per year since 2012). During 2013-2021, 8 to 13 applications were received per year, and the average approval rate during that period was 42 %.

In the early years of the WNRB, the average funding was about €38,000 per project. Since 2017, the average funding increased to between €40,000 and €50,000. There is large variation in approved amounts: the lower bound has lately been at around €6,000 per project, but is usually at €20,000 to €30,000. The upper bound is at about €100,000.

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[11] Trafikverket has organized its research areas into seven portfolios: 1) Planera, 2) Vidmakthålla, 3) Möjliggöra, 4) Bygga, 5) Sjöfart, 6) Luftfart och 7) Strategiska initiativ *(freely translated as 1) Plan, 2) Sustain, 3) Enable, 4) Build, 5) Maritime, 6) Aviation and 7) Strategic Initiatives)*

[12] See section ap.12.2 in Regleringsbrev för budgetåret 2022 avseende Trafikverket

[13] Regleringsbrev för budgetåret 2023 avseende Sjöfartsverket

[14] Data for funding decisions per project was not available prior to this period.

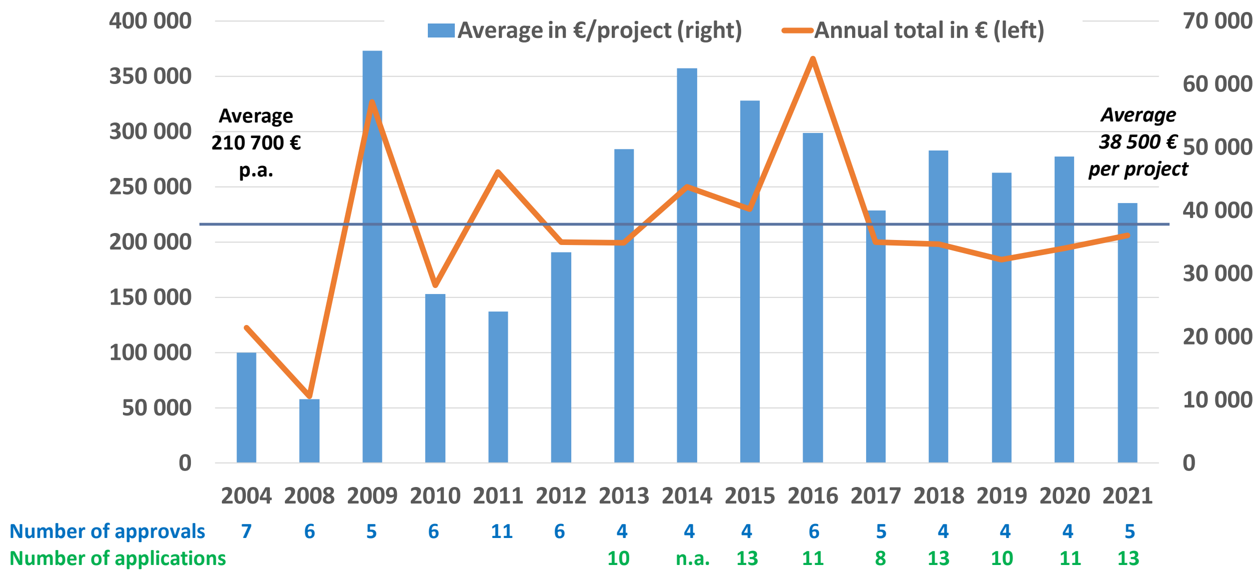


Figure 11 Funding, in 2004 and 2008-2021, as total and average/project in €, per year.

The real value of the funding has diminished substantially since the 1970s. Purchasing power of €1 in 2020 was approx. €1.40 in 2000, i.e., 40% higher than twenty years previously. The purchasing power of 10 SEK converted to EUR in 2020 was approx. 11 SEK in 2000 when converted back from EUR.

Over time, several other substantial funding sources have emerged, with an increasing influence on relevant projects. In addition to the real value of the funding, Universities', and research institute's cost structures, for infrastructure, staff and administration have become heavier, further reducing the available funding for the content in the actual projects.

3.2.2 Possible changes in the Swedish R&I funding

Sweden has several organisations for public funding of R&I (or research and innovation) projects. One effect of this heterogenous system is that over 800 Calls for proposals were published during the last four years. This can cause inefficiency, unnecessary administration, overlap and gaps – eventually lowering the value for money in the national R&I funding structure, and hampering the scientific quality of the work. The structure also tends to fund shorter and smaller projects and cause researchers to spend disproportionally large amounts of time modifying applications for different Calls.

A comprehensive governmental research funding investigation (FoFin) started in 2022 and its mid-term report was published in May 2023 [15]. It proposes that all R&I funding is transferred to three main agencies: Science, strategic research and innovation. FoFin aims at making research funding processes more efficient and accurate, but it is important that the proposed structure does not only fund big projects, but manages to cooperate with important niche areas too.

FoFin does not impact the WNRB projects under evaluation in this study, but it is important to keep an eye on this development. FoFin's final formulations and possible changes to the Swedish R&I funding system may have an impact on Swedish WNRB funding too.

[15] Forskningsfinansieringsutredningen (research funding investigation)

3.2.3 Complementary funding

To gear up total project funding, good work has been done by the WNRB, as are reported later. This has further improved the WNRBs "value for money", fostered interdisciplinary cooperation and established a strong eco-system for future research cooperation. Using a competent small programme such as the WNRB cooperation to catalyse and benefit from complementary funding is excellent, for the winter navigation field as well as for the external funding sources, that are given an opportunity to benefit from the WNRB.

3.3 Calls, assessments, and decisions

3.3.1 Timeline

The cooperation has been governed by the board of WNRB, with the bilateral contractual agreement between the Finnish Maritime Administration and the Swedish Maritime Administration remaining in relevant parts the same since 1972.

A desirable timeline for the Call and decisions to applicants uses the example of the 2019 Call:

- Call text available — 28 June
- Deadline for applications — 13 September
- Announcement of decisions — 18 October
- Earliest start of projects — 18 November

Some later Calls have, however, had a delayed timeline due to difficulties in guaranteeing sufficient funding for the next fiscal year. Lack of ability to allocate long-term funding for the WNRB projects, no matter if the funded projects are short or long, causes damage and inefficiency. For short (one-year) projects, in need of a "winter period", delayed funding decisions understandably are causing extra challenges.

3.3.2 Process for evaluation and recommendations

The steps for managing proposals, assessments and recommendations are:

1) Call opens and proposals are submitted.
2) Applications are read and assessed based on their usefulness in view of contemporary and usually often very pragmatic goals.
    a) The assessment is done exclusively by representatives of the agencies, no external "scientific peer review" process is utilised.
3) After pre-assessing applications, they are submitted to the WNRB board, with representatives from the governing organisations.
4) Each of the four agencies representatives assesses the applications, formulates recommendations and a joint decision meeting is held (typically) every autumn to discuss and formulate recommendations decided by the WNRB.

3.3.3 Assessment criteria for submitted project proposals

The following indicative weights of the assessment criteria are extracted from the 2022-2023 WNRB Call. Similar criteria and weights have been used during the past decade. The assigned weights and respective assessments provide a guideline for approving individual projects.

In addition to the proposed adjustment of the total financial resources, the weighting, guiding both the applicant, assessment process and the WNRB R&I field would benefit from an annual consideration and possible small adjustment. So far though, the weighting below has served the WNRB well. The criteria in the Call for research projects for the year 2023 are as follows:

Relevance (35%):

o Is the project in line with the aim of the Call?

o To what extent does the project contribute to a sustainable winter navigation transport system?

o What defined winter navigation problem should the project solve?

Quality (15%):

o How will the project contribute to the technical and scientific development?

o Does the project contribute to moving the research front and knowledge forward?

o Is the project considered to be of high scientific quality?

o Does the project include a new idea or innovation?

Viability (15%):

o Are there risks involved in accomplishing the project?

o Are the goals of the project concrete, well-defined and reasonably ambitious?

o Is the draft work plan concrete and is the schedule realistic?

o Do the actors have the right skills, competences and proper resources to complete the project?

o Is the budget reasonable in relation to the intended efforts and objectives?

Impact (35%):

o Is there an identified need for project results, such as a clear knowledge gap or market potential?

o To what extent can the project be of use, for example through building knowledge, publications, new types of goods, services or processes, or for commercialization?

o What ambitions does the project have for spreading the results? Is there a plan for how the results should be utilized and disseminated?

o Are the end-users of the project results represented in or participate in the project?

The thematic division of the 2023 Call is shown in **Appendix 1**. The titles of the published reports are shown in **Appendix 2**.

3.4 Considerations regarding the Calls, evaluation and approval procedure

Working through the documentation, processes and results as well as interviewing several participants in the WNRB cooperation, we would like to raise some issues for future decisions and considerations. It is easy to jump into changes and “improvements” but the WNRB, for its purpose and important role, is a well-established hands-on cooperation with very high yield. It is much appreciated and well managed. Changes and “improvements” can therefore easily lead to negative effects, and given the small community it is easy, in all good sense, to spoil the programme. Implementation of any changes need to be very carefully managed and the somewhat deviant character of the WNRB, compared to big and long-term programmes, ought to be appreciated and used, not smoothed out to fit a standard governance model. Our main considerations are mentioned below.

The active and eligible research community in Sweden and Finland is small and well known to all involved parties. The WNRB is not widely known beyond this community, but Calls are widely cited and distributed also in international branch media. The WNRB needs to consider if a stronger outreach beyond the existing community would be beneficial.

3.4.1 The Call and assessment process

The Call and the assessment process are seen as pragmatic both by applicants and the WNBR. The WNRB has straight-forward application procedures, which is a good thing when applying for these small-scale funds. Both technical and formal requirements to submit an application and also to report project results are manageable, no-nonsense and appreciated.

More extended requirements, both for application and reporting, add cost and bureaucracy to small projects, establishing thresholds for applying and inefficiency in reporting, lowering yield and value for money. The trade-off between invested time and effort does not pay off, especially for applicants, and to keep the same level of results the total budget needs to be increased.

3.4.2 New and complementary areas

Cooperation with and contribution to neighbouring R&I areas is advantageous for several reasons. Multidisciplinary solutions, where traditional narrow research fields interact for mutually beneficial achievements, are gaining momentum within publicly funded R&I. Today such cooperation exists, and several good solutions have been brought forward, but this approach can be strengthened further.

One strategy to achieve this is a broader acceptance of projects within the WNRB portfolio. Another strategy is to actively strengthen processes with projects, where benefits from cooperation seem available. A balance between these strategies also need to keep up the good value for money in WNRB programme.

3.4.3 Funding levels

When the WNRB started, a proper total funding level was decided. Unfortunately, its purchasing power has decreased drastically in real terms compared to the 1972 funding. According to purchase power statistics of Bank of Finland and Sveriges Riksbank, adjusting the level of funding for inflation would mean a 50% increase to the annual level now at €200,000 (see **Appendix 3**). Adjustment decisions need to be taken into account:

i) Restoring the actual funding level to the 1972 level is an important, much needed and a straightforward decision.

ii) Increased funding above this level may fail to add value as it may generate more demanding processes, especially if the funding would exceed public procurement threshold values that require competitive bidding.

iii) Keeping funding at today’s low levels risks the programme to diminish its relevance and impact.

3.4.4 Pre- and post-actions for Calls and applications

In view of the applicants, the preparation and follow-up of the Calls has the following features:

- Some possibilities exist to improve the pre-application process. The benefit would be to refine project objectives and research tasks, complementary projects, solutions, funding, and partners. It could also foster engagement to fund deployment and usage of possible outcomes. Our interviews also show that a more open preparation of the focal themes could be considered.
- Some discussions and elaboration of potential timely and topical issues have taken place before the Calls between the WNRB agencies and tentative applicants because many of the potential applicants are regularly engaged with the authorities in other on-going winter navigation projects, such as the WINMOS projects (more on WINMOS in section "Impact assessment of conducted WNRB research").
- Projects have also raised the possibility to have an improved dialogue with the WNRB, as part of the assessment process or after a decision to reject project funding has been notified. In our opinion this is not desirable, but actions can be taken to improve the dialogue, before and after the assessment and decisions, guaranteeing that there is no risk to influence the decisions.
- One step in this direction could be to consider the following actions during the three phases:
  - i) Pre-application: An open information event or a seminar for interested parties after the yearly Call has been announced. This could be used as a platform to discuss the topics and explain opaque formulations in the Call. This is also positive for the WNRB and others, as examples show that such seminars are often mutually beneficial.
  - ii) During assessment: No dialogue.
  - iii) Post-reject: Feedback to the WNRB and general feedback to the applicant might be useful, but detailed feedback is both time-consuming and may give the applicants the false impression that "if we fix these issues our application will be approved", which may create a never-ending story.

4 Project results and their impact

The WNRB programme has been able to select strong and relevant projects, which have fostered dissemination and networking, generated synergies, and a broad usage of project achievements within the relevant organisations and industry. The programme has also stimulated the understanding of many relevant to winter navigation issues, fostered solutions and managed to deploy results well to key stakeholders both in Sweden and Finland and beyond.

We have found that the WNRB programme has been well managed, the projects have given good results, effects and excellent value for money and the fruitful cooperation has good potential to add value for another 50 years.

Since the start, over 120 projects have been approved funding have delivered results and final reports. The average funding is €38,000/project. The projects comprise research, development, innovation, and demonstration activities. Below we summarise:

1) A content analysis of the research reports published in 1972-2022

    By September 2023, the report series reached no. 127, of which reports up till No. 123 have been analysed in this evaluation

    Some report numbers have several sub-reports, and report numbers 100 and 101 have not been used due to a numbering error. As a result, the total number of separate reports or sub-reports in the WNRB series by September 2023 is 132

2) A summary of the number of WNRB reports, by theme and decade

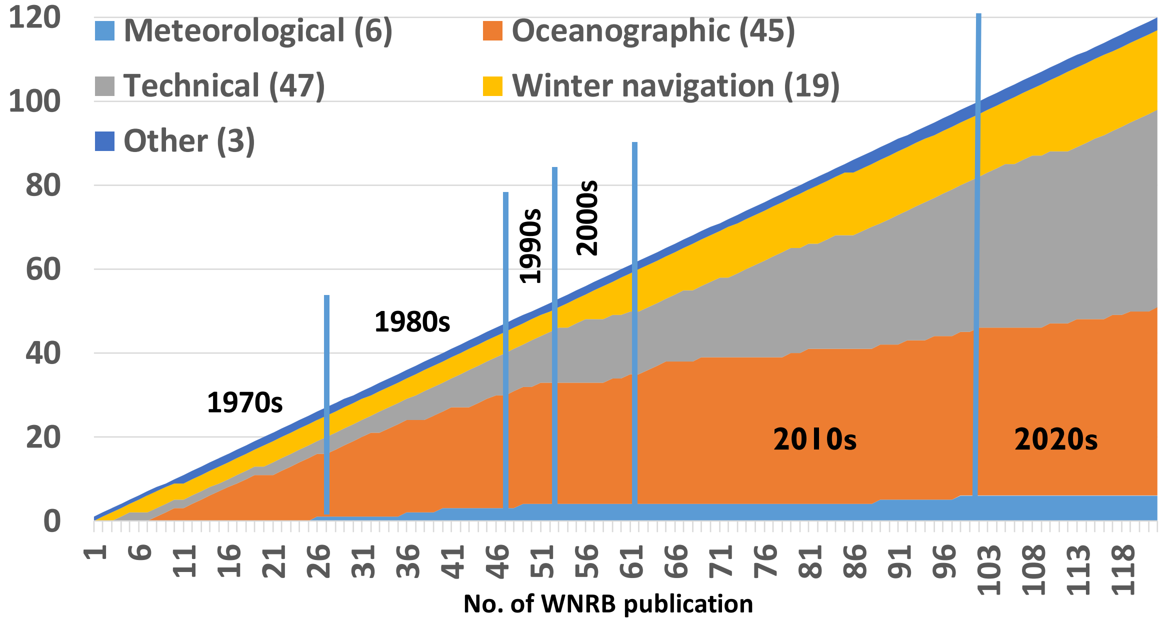
3) A qualitative and impact assessment of WNRB research, based on initial interviews of both authorities and researchers coupled with literary analysis

The titles of all the published WNRB reports can be found in a chronological order in **Appendix 2**, and the full reports can be accessed here.

4.1 Numerical overview of WNRB projects by theme and decade

The division of published WNRB reports by decade and theme are shown in **Figure 12** and **Figure 13**. WNRB project activity in the 1970s and until the mid-1980s was intensive and focused mainly on oceanographic issues. This was a period with frequent cooperation projects between Finnish and Swedish research groups.

From the 1990s until the first decade in the 2000s was a period with somewhat fewer projects, but the programme gained momentum again in the 2010s and the 2020s. This is likely reflecting the situation, where both Finland and Sweden had reached a state of *status quo* in icebreaker operations and management, and there was no immediate need for constructing new icebreakers, for example.



- *Report No. 16 from 1975-1976 comprises nine (9) sub-reports; they appear here as just one report*
- *Only the title of Report 22 was available; Report 24 was stored in its stead*

Figure 12 Content analysis of WNRB reports by theme and decade in 1972-2022, by year of WNRB publication approval. In some cases, actual research has been completed one or more years prior to the publication.

Over the past decade, WNRB projects have had a good level of activity. The focus has changed to technical and regulatory challenges, which have become more relevant due to the regulatory changes within the IMO and EU. Since the 1990s, projects have had little cooperation between Finnish and Swedish groups.

	1970s	1980s	1990s	2000s	2010s	2020s	Total
Meteorological	1	2	1	0	2	0	6
Oceanographic	16	11	2	1	10	5	45
Technical	4	6	2	3	21	11	47
Winter navigation	5	0	0	4	6	4	19
Other	2	0	0	0	1	0	3
Total	**28**	**19**	**5**	**8**	**40**	**20**	**120**
...of which							
Finnish	15	10	2	7	30	18	82
Swedish	8	6	3	1	10	2	30
Joint FI-SE	5	3	0	0	0	0	8

High activity in the 1970s until mid-1980s

Very low activity in the 1990s and low in early 2000s

Very high activity in the 2010s and high in the 2020s

Shares by themes:

Technical (39 %) and Oceanographic (38%) almost 4/5 of all reports by indicative main themes.

Winter navigation (19%) and Meteorological (5%).

”Other” comprises symposium reports (3%).

Figure 13 The number of WNRB reports by theme and decade in 1972-2022, by year of WNRB publication approval. In some cases, the actual research work has been completed one or more years prior to the publication.

Several reports could be labelled under two main headings, especially with meteorological and oceanographic studies. Thus, the division by themes in **Figure 12** and **Figure 13** is therefore indicative (see also **Appendix 4** and **Appendix 5**).

4.2 Key contributors of conducted studies

Examples of recent recipients of research grants from the Finnish-Swedish Winter Navigation Research Board is shown in **Table 6**. The list is not comprehensive, because it is not always clear from the reports, which entities have contributed to the studies. Also the role of individual contributors cannot exhaustively be deducted from the reports. Over the years, a bit more than 100 individuals have (co)authored the reports. Several authors have contributed to more than one report.

Table 6 The most frequent contributing entities in the conducted studies since 1972 (not in ranking order)

Finland	**Sweden**
• Aalto University (Marine technology)	• Swedish Meteorological and Hydrological Institute (SMHI)
• Finnish Meteorological Institute (FMI)	• Kalmar Maritime Academy
• Technical Research centre VTT	• SSPA* (Maritime Center in Gothenburg)
• Several other Finnish universities	• Chalmers University of Technology (Mechanics and Maritime Sciences)
• Aker Arctic Ltd.	
• ILS Ship Design & Engineering, a consultancy	*) The abbreviation comes from Statens Skeppprovningsanstalt, founded in 1940

It is not surprising that the number of key entities contributing to winter navigation research is not very large, because the topic is so specific.

4.3 Qualitative assessment of the conducted research

The research conducted in WNRB funded projects has been almost exclusively applied research and dealt with pragmatic and relevant real-world phenomena. They have targeted specific, contemporary, and needs-based issues as defined by the Board, which have had strong linkages to contemporary regulatory issues or technological challenges.

Application of novel methods and techniques can be seen especially in the 1970s and 1980s, and again in the 2010s and onwards. There have also been numerous studies addressing new theories and model building, especially within technical sciences.

Results and experiences from research projects funded by WNRB are often being taken further in other research projects, which include:

i) Typically highly ranked academic journal articles

ii) Doctoral theses

iii) Improvement of technological and design know-how of design agencies.

Overall, the reports meet good to (very) high scientific standards.

As an annual source of funds, WNRB has been very useful. But money is only one part: the invaluable element is the access to Icebreakers and other field tests, which would be very difficult and/or costly to organise without the WNRB cooperation. Field tests often require substantial complementary in-kind funding in time, resources and access to expensive equipment.

The added value of the WNRB funding appears to be very good or even excellent especially in view of the funds channelled through it. Specific cost-benefit calculations are difficult, but numerous good examples exist. A recent outstanding example is report No. 121 on the icebreaker channel widening issue, which had a direct impact on finding, designing, building and deploying the most feasible and effective technical solution to Sweden's new icebreakers. The cost saving potential of this solution over the life cycle of the new icebreakers is estimated in millions of euros.

4.4 Impact assessment of conducted WNRB research

WNRB funding has had significant and durable leverage effects. Our assessment is summarised as follows:

a) Results have a direct relevance to on-going broader research and development work in this field.

b) The funds have a very substantial leverage effect.

c) An important feature is that WNRB Calls and funds have been stable and predictable, and with a relatively high success rate (> 40%). This stability attracts good researchers, partners and projects which partly compensates the relatively small amounts of funds per project.

The WNRB share of all Finnish and Swedish public sector funding on winter navigation research is currently approximately 1 %. However, the stability and engagement of competences, partners on interesting and relevant research issues combined with the close community has made WNRB very attractive for competent researchers, even when the actual amount funds is relatively small.

It is fair to say, that the stable and long-term WNRB funding has been very important in maintaining and increasing winter navigation research competence in Finland and Sweden. Without it, large and complex winter navigation projects would have been much more difficult and costly to generate and execute.

For example, the EU part-funded winter navigation research projects have been very large, such as the Winter Navigation in Motorways of the Sea (WINMOS) projects. Their combined budget is €345 million, of which EU contribution has been almost €130 million:

i) WINMOS I (till end-2015), budget €139 million, of which €29.6 million was received from EU TEN-T's Motorways of the Seas funding instrument. About €24.3 million of TEN-T funds were used to co-finance about 25 % of the cost of the new LNG-powered Finnish icebreaker Polaris, delivered in 2016.

   Lead Partner: SMA; other partners Finnish Transport Agency, Finnish Meteorological Institute, Aalto University (FI), Novia University of Applied Sciences (FI), ILS Ship Design & Engineering (FI), Image Soft Ltd. (FI), Aker Arctic Technology Inc. (FI) and Estonian Maritime Administration

ii) WINMOS II (2016-2019), budget €19 million, of which €6.6 million was funded by Connecting Europe Facility (CEF), a EU funding instrument.

   Lead Partner: FTIA; other partners SMA, Arctia Icebreaking Ltd. (FI), Aalto University (FI), Novia University of Applied Sciences (FI), ILS Ship Design & Engineering (FI), and Estonian Maritime Administration

iii) WINMOS III (2023-2027) budget €186.9 million, of which €60 million was funded by CEF. Majority of the funds will be used in connection to the new Swedish icebreaker to be completed in 2027.

   Lead Partner: SMA, other partners FTIA (Finland's share of the budget €2.9 million), and Estonian Transport Administration as an associated partner

Our impact assessment confirms that funds channelled through WNRB have, overall, been particularly well spent.

4.5 Considerations for future directions of WNRB

During its existence, WNRB has been able to adapt to changing times, and to focus on important and timely issues, and also get the work done in a cost-efficient way. There is a risk that important research areas on lower Technology Readiness Levels[16] (See **Figure 14**) and with less political impact, get less attention.

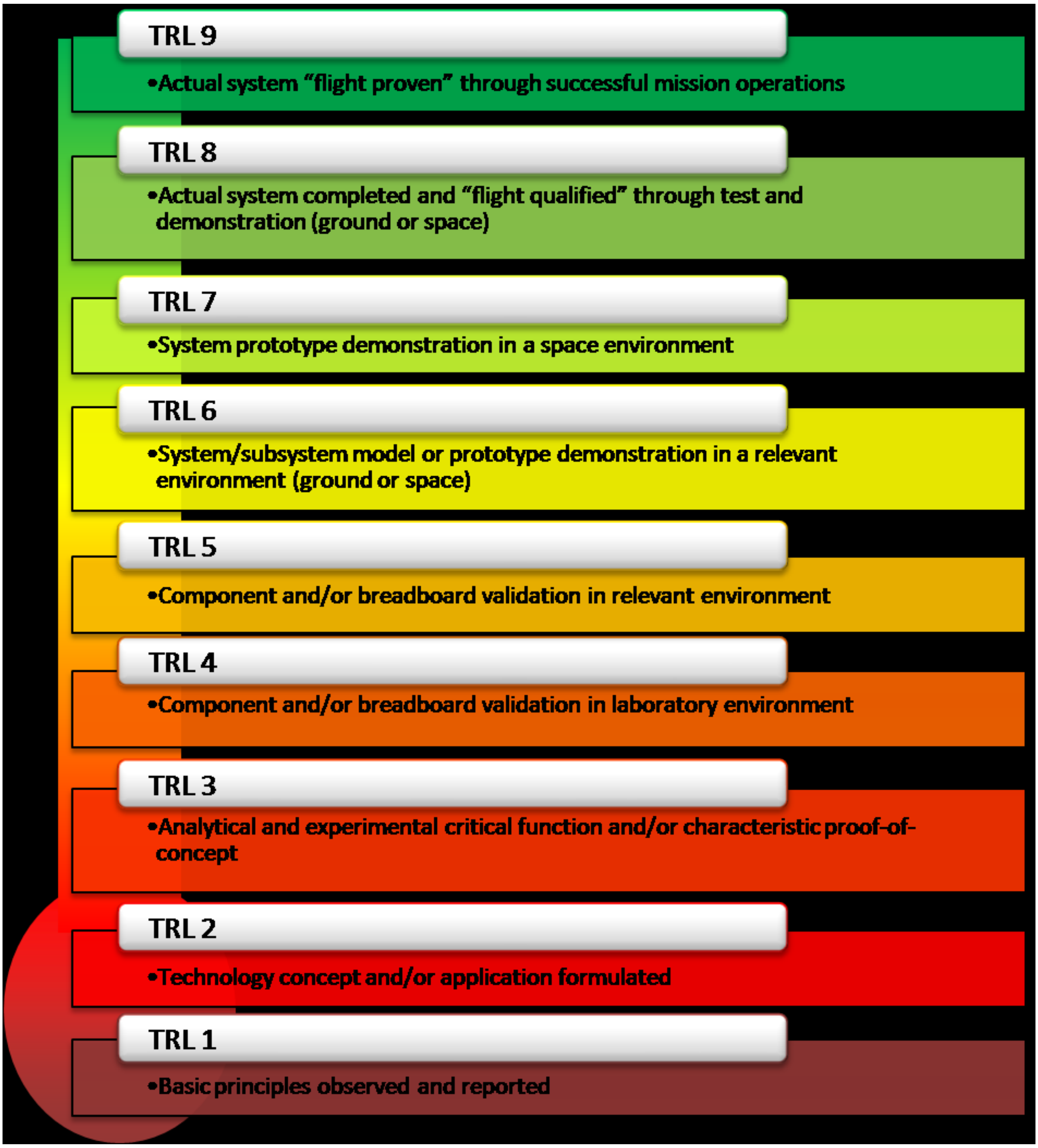


Figure 14 Technology Readiness Levels. A TRL number is obtained once the description in the diagram has been achieved. Source: NASA

[16] Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels.

A possible focus over the next years could be to strengthen relevant non-technical areas of winter navigation, including, but not limited to socio-economic analyses. One such emerging issue is the rapid growth of windmill parks in ice-infested waters in the Gulf of Bothnia, and their compatibility with winter navigation needs. Approaching such themes could also mean longer projects synchronised with complementary funding and partners.

WNRB projects have been well managed, and they show exceptionally good value for money. The trend in later years toward shorter and smaller projects, might cause depletion of projects and knowledge in areas where more long-term engagement is needed. These include, for example, meteorological and oceano-graphic studies. These are characterized by a large portion of basic research and studies, where field tests are particularly valuable. This type of knowledge can be very expensive to re-establish if the level of activity has remained low for too long.

Since the selection of projects is based on quality parameters, Finnish projects have shown to be more numerous than the Swedish ones. This largely reflects the much higher volume and longer engagement in Finland with technologies connected to winter navigation: about 60% of all icebreakers in operation in the world today have been built and about 80% designed in Finland.

Traditional research projects increasingly benefit from interdisciplinary cooperation and complementary funding. This applies also to WNRB projects. Digitalization, AI/AR, IoT and Big Data as well as behaviour sciences, new energy forms for propulsion and storage of energy combined with development in business logic and a mix of private and public funding are important challenges and possibilities to manage in the future also for WNRB.

5 Conclusion

5.1 Noticed changes in applications and approved projects

The 1972 agreement and the establishment of WNRB was farsighted and has contributed to keeping ports open, enabling all-year operation, with large benefits to Finland and Sweden.

Activities in the WNRB projects in the 1970s and until the mid-1980s were intensive and were often focussed on oceanographic or meteorological challenges. This was a period with frequent cooperation projects between Finnish and Swedish research groups.

From the 1990s until the first decade in the 2000s was a period with fewer projects, but the programme gained momentum in the 2010s and the 2020s. Over the past decade or so, the WNRB projects have prospered, with good level of activity. The focus has changed towards technical and regulatory challenges, which have become more relevant due to the regulatory changes within the IMO and EU.

We also notice that funding of Finnish projects dominates, both as applications and in approved projects, and especially in technical projects. Since the 1990s, projects have had little cooperation between Finnish and Swedish groups.

These changes can be due to the reduced total funding (in real terms), resulting in shorter project times, a shift to more technical projects on higher TRLs, and hands-on implementation of project results. It is important to consider also more long-term projects addressing activities at lower TRLs, establishing a project portfolio with projects along a larger span of the TRL scale.

One particular notion is that after a relatively long period of low activity, it might be time to seek more meteorological and oceanographic studies to be funded. This is also motivated by the fact that climatological conditions are ever changing, and the pace of these changes appear to be growing.

5.2 A long-term, stable, small, efficient and important community

The small WNRB community, focused and predictable Calls over the years together with hands-on management have yielded projects of good to high quality and efficient management. This has resulted in excellent value for money to the winter navigation field. Below is a short list of some proposed actions that might help to further improve the programme:

Timing of Calls and thereby decisions/start of projects has had some synchronization problems lately, which is not good for short projects in need of winter testing. Compliance with the previous schedule need to be improved.

The Calls and their assessment and decision process are seen by the applicants as a straightforward and efficient, but somewhat opaque, where feed-back to applicants is limited, both for approved and rejected project proposals.

We have mentioned possible modifications to improve this both during the pre-application and post-decision phases. There is potential to improve the quality and targeting of applications as well as to develop an increased interest from researchers through better and more transparent dialogue.

There is room for improvement in how results are reported and disseminated outside the WNRB community. There is also potential to engage complementary disciplines and funding, agencies, academia, and industry, thus strengthening complementary resources to the WNRB.

The engaged, experienced and skilled team managing the WNRB is efficient, but quite small. With a more developed scientific content, increased funding levels, longer projects and larger project teams, additional resources and complementary competences would be needed.

Some projects are co-funded, and the WNRB funding may provide a relatively small add-on to other projects. To put the annual €200,000 of WNRB into perspective, also other sources of funds are available for winter navigation researchers. For example, WINMOS projects alone have generated approx. €130 million in EU funding since the early 2010s. The direct funding from transport agencies has been significant, such as the resources used to prepare Sweden's procurement for 2+1 icebreakers.

In addition, Finnish shipping-related foundations typically share €70,000 to €100,000 annually to winter navigation research, often as small personal grants rather than funding specific projects.

In conclusion, despite the limited funding and slimmed management resources for WNRB, several larger projects have been possible to execute. Areas of responsibility and mechanisms for complementary competences, disciplines and funding are, generally speaking, becoming more frequent in R&I funding. The WNRB has managed this in a good and focused manner and without unnecessary administrative overheads.

5.3 The Bay of Bothnia and winter navigations needs in the near future

In 2022, about 10 million tonnes of cargo was handled in Swedish seaports in the Bay of Bothnia during winter months, but the share of Swedish-flagged vessels in winter navigation has diminished dramatically since the mid-1990s (**Figure 15**).

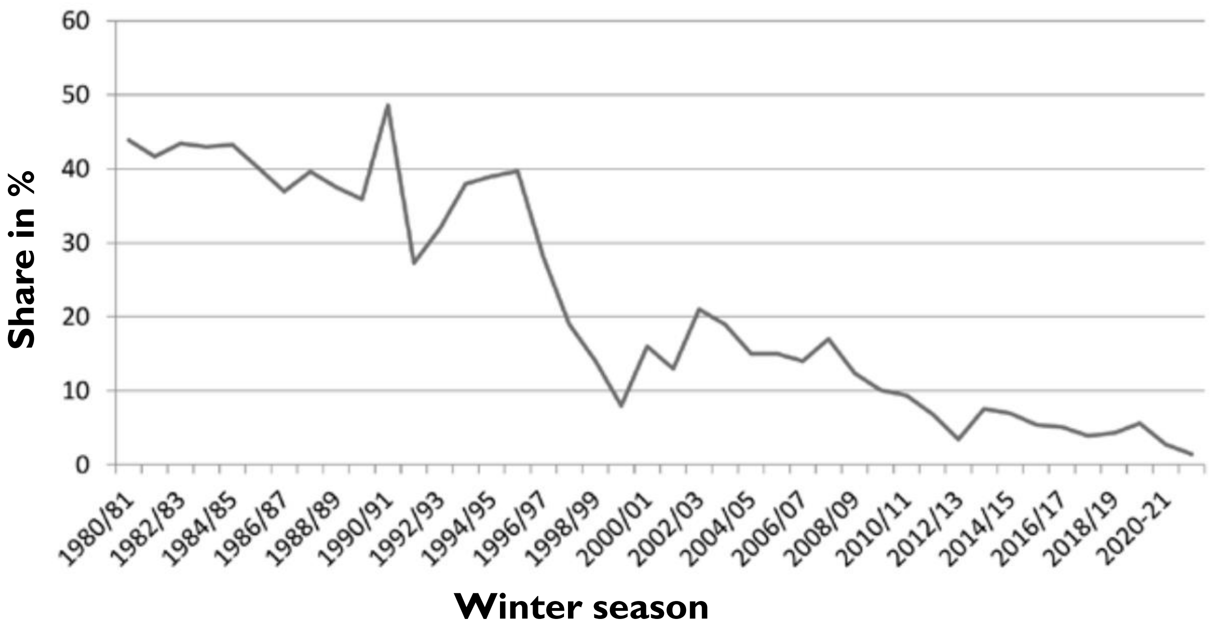


Figure 15 The share of Swedish-flagged merchant vessels in winter navigation from winter season 1980/1981 till 2020/2021 in percent.

Source: A summary of the ice season and icebreaking activities 2021/2022, SMA 2022

The share of Finnish-flagged vessels in winter navigation is significantly higher than in Sweden. About half of maritime trade by ro-ro and ro-pax ships to and from Finland is carried by ice-strengthened Finnish-flagged vessels. This share is the largest in the world. Also well over half of all petroleum product shipments and a significant share of bulk shipments to and from Finnish ports in the Bay of Bothnia are carried with ice-strengthened vessels registered in Finland.

This is reflected in **Table 7**, which shows the share of Finnish-flagged vessels of all port calls in Finland in 2021. The statistical unit (port calls) is not necessarily identical with the Swedish data for winter navigation in **Figure 15**, as the latter may also be counting individual vessels rather than port calls. However, the difference between Finland and Sweden in this respect is evident when these two sources are compared.

Table 7 The share of Finnish-flagged vessels of all port calls and the number of all port calls in Finnish seaports in 2021. Statistical source: Traficom

Port calls to Finnish seaports in 2021	Share of Finnish-flagged vessels*	Number of port calls in 2021
Passenger car ferries	57 %	14 000
Ro-ro and ro-pax vessels	53 %	4 500
Crude oil tankers (> 30 000 NT)	32 %	550
Product tankers (< 30 000 NT)	16 %	1 400
Dry bulk vessels < 10 000 NT**	18 %	6 800
Multipurpose vessels in container shipping	<6 %	1 350
Dry bulk vessels > 30 000 NT**	<2 %	750
Chemical and gas tankers	0 %	800

*) Practically all of these are ice-classed vessels

**) There are no Finnish-registered dry bulk vessels between 10 000 NT and 30 000 NT

Finnish Bay of Bothnia seaports from Vaasa to Kemi handled 7.1 million tonnes of cargo from December 2021 till April 2022. About 2 million tonnes of this cargo is between Finnish and Swedish seaports in the Bay of Bothnia. Net cargo volume in Bay of Bothnia seaports during winter months was therefore about 15 million tonnes.

Substantial port investments are made, for example, in the port of Luleå, where cargo traffic is forecasted to increase from 8 million tonnes in around 2022 to 32 million tonnes by 2030. Northern Sweden accounts for 65% of Sweden's raw material exports and the port of Luleå currently handles SEK 15 billion (~€1.5 billion) worth of goods / year.

A similar, yet less dramatic development is foreseen also on the Finnish side of Bay of Bothnia with several mining and energy related projects.

The Baltic Sea is gaining importance as an essential infrastructure complex for climate smart logistics. Bay of Bothnia also ties together two EU transport corridors, the North Sea-Baltic and the Scandinavian-Mediterranean corridor and acts as an important hub in the Arctic Gateway cooperation.

5.4 Regulatory developments, Ice-class rules and areas of future emphasis for WNRB

Regulatory pressures on winter navigation remain high and are mounting. The details of EU's Fit for 55 and FuelEU Maritime processes will give more specific guidance on potential themes. One such (on-going) theme is how Finnish-Swedish Ice Class Rules (FSICR) need to be adapted to these changes.

Research funded by WNRB is much needed also in the future to analyse and tackle compliance challenges of winter navigation vis-à-vis the regulatory changes within IMO and the EU. More work is needed to reconcile the requirements of EEDI, EEXI and CII and their possible future elaborations vis-à-vis FSICR and winter navigation capability, engine power and emissions. Actual ice-going capability of new IA cargo vessels has already been troubling, especially for ro-ro and ro-pax vessels.

Addressing the impact of regulatory changes on winter navigation is increasingly important after EU's decision to include all ships over 5,000 GT in its emission trading scheme EU ETS as from 1 January 2024. However, there are several methods to calculate ship's emissions. The extra challenge for ro-pax vessels is how to assign emissions between passengers and cargo, because these methods give widely differing results. This, in turn, can have a very significant impact on shipping companies need to compensate their emissions through the EU ETS. Even for a relatively small ro-ro/ro-pax shipping company operating in ice-infested waters within the EU, the additional cost from emissions trading can be over €10 million per year.

These regulatory needs have been reflected in several WNRB studies. For example, the first WNRB funded studies addressing the EEDI were published in 2014. Report no. 78 was entitled "POSSIBILITIES TO DECREASE THE ATTAINED EEDI OF THE FINNISH MERCHANT SHIPS" authored by Mr. Harri Eronen and Prof. Kaj Riska from ILS Oy (Finland), and Report No 88 entitled "EEDI AND FINNISH-SWEDISH ICE CLASS RULES" by Mr. Victor Westerberg from SSPA (Sweden).

In other words, EEDI type regulations have been on WNRB's "radar screen" for about a decade, which is evidenced in the specific themes of the Call for the 2022-2023 winter season (see **Appendix 1**). In the Call for the 2020-2021 season, a similarly motivated special need was formulated as follows:

> *"The Winter Navigation Research Board invites project proposals that investigate the effect of different modeling methods and parameters on engine power tests in ice channels as well as research that compares full-scale results with model tests. The results will be used in making updated guidelines on how model tests showing compliance with the engine power requirement of the Finnish-Swedish ice class rules should be conducted."*

Continued work may be needed with the 5-knot FSICR requirement in model tests, which are currently not standardised. This initially resulted in big differences in vessel classification by different agencies and approvals across administrations, but the recent "Guidelines for application of the 2017 FSICR" published by Traficom in 2019 have helped a lot.

The development and implementation of Polar Code (PC) within IMO resonates also with FSICR and their policy and regulatory issues. The two are inherently different by design, and regulate different things:

a) FSICR is designed for actual winter navigation capability of merchant vessels, and emphasise engine power and propulsion in addition to hull strength etc.

b) IMO's Polar Code focuses almost exclusively on hull strength to withstand ice pressure without engine power requirements.

One item for further research could be the adaptation of FSICR to smaller craft used e.g. in island ferry traffic or in road ferries as part of the road network both in Finland (incl. Åland) and Sweden. This would be highly relevant in public procurement tenders nowadays used in Finland and Åland, and would also benefit the governmental (Färjerederiet) and private sector service providers in Sweden. These operations are very important for residents, holiday house owners, tourists and businesses depending on these services. Currently, there are no clear guidelines on how ice class regulations are interpreted and certified in smaller crafts. At the same time, the rapid progress in, for example, battery storage and electric propulsion technologies, is beginning to enable cost-efficient renewals of these fleets towards low to zero emission solutions.

6 Recommendations

Our investigation shows that the WNRB has worked hands-on, skilled, and efficiently, and the funded projects have resulted in very good and usable results, both from a scientific and practical points of view. This is very positive, both in terms of "what" and "how" the WNRB has managed the programme.

It is important to continue the skilled and cost-efficient work that the WNRB has delivered over the past 50 years. The board and the small but highly skilled winter navigation research community together with private sector expertise in Finland and Sweden have delivered highly usable results. These results have also effectively been deployed and taken into operation. The WNRB is and ought to continue as a niche programme, where renewal of the agreement and adjustment of the funding levels are done.

Actions are needed to strengthen the WNRB to meet heterogenous and changing demands from industry and politicy-making, interacting with other research fields and networks. This should be so that larger programmes and organisations do not swallow the WNRB. Much of the strength, value for money and benefits in the WNRB lies in the small community and competences engaged today. It is important to keep it this way and that the governing agencies do not drown the WNRB or the funded projects in bureaucracy.

There are also challenging trends, threats as well as possibilities for winter navigation in Finland and Sweden. Based on our evaluation of the WNRB programme our recommendations are as follows:

1) Restore the real purchasing power of the funding level to what it initially was, or was at least in the 1980s. We propose an increase of 50% (or more), whereby the annual funding would reach €300,000 (or more).
2) It is important that the WNRB can secure necessary funding also in the future, and the responsible agencies have the mandate to take funding decisions. This would strengthen the well-established and efficient hands-on approach to meet the prerequisites for the next 50 years. This would also help the shipping companies to meet the logistical demands of shippers (i.e. their clients), and to maintain tonnage capable of navigation in ice-infested waters.
3) Foster funding models enabling longer projects and work on issues at lower Technology Readiness Levels (TRL). This could mean encouraging interdisciplinary projects, system demonstrations and the engagement of complementary competences. This could generate interdisciplinary projects and studies on issues in need of longer funding and/or addressing themes at lower TRLs.
4) Encourage more dialogue with the research community in relevant areas.
5) Strengthening of the WNRB needs to be managed without losing its slim and agile management and informal networks between agencies, researchers and shipping as well as shipbuilding industry. This has enabled a very cost-efficient ecosystem for this programme.
6) There is big potential for other research platforms to learn from the WNRB and its responsible agencies how they have managed this programme. This type of outreach towards other research platforms and research funding schemes is strongly encouraged.
7) Actions could be taken to strengthen the scientific competences within the WNRB that may mean longer projects, and projects dealing with issues at lower Technology Readiness Levels. It is important increase dialogue with industry, the use of complementary funding sources and engage disciplines relevant to smart maritime development. At the same time, the Board should prevent the development of unnecessary administration pertaining to WNRB processes. These actions would need;

a) external scientific review of applications, and increased cooperation with networks for complementary research fields,
b) longer funding commitments
c) increased dialogue with the scientific community, with relevant and complementary disciplines to the WNRB field.

8) Evaluate possible benefits from preparatory work, policy learning and peer review processes, with more efforts invested in setting up the project as well as deploying experiences, results, and achievements.

9) Strengthen the feed-back both to dismissed and approved proposals, with the ambition to further professionalize the WNRB's field of operation.

10) We also suggest novel research areas or objects of analysis for the WNBR. These include, but are not limited, to:
i) socio-economic analyses pertaining to winter navigation;
ii) co-existence of windmill parks and winter navigation in ice-infested waters;
iii) Future regulatory issues with FSICR and IMOs Polar Code;
iv) the adaptation of FSICR (or equivalent) to smaller craft used e.g. in island and road ferries that are widely used in year-round traffic both in Finland, Åland and Sweden.

An additional technical recommendation for the WNRB is that the reports it publishes are cited in such a way that the period within which the project has been accepted, performed, and published as well as the affiliation of all the authors are clearly documented.

7 Summary of the WNRB evaluation

Since its establishment in 1972, the WNRB programme has funded over 120 projects[17]. The projects show good to excellent impact, scientific quality, and value for money. This can be said, even if the funded projects are small and short in duration (almost invariably less than 12 months).

Management of the programme, both on the Finnish and Swedish side, has been cost efficient and very well conducted. It has turned out to be flexible and agile, adapting to changing needs, and using a hands-on approach.

WNRB has also been actively following IMO's and the EU's regulatory changes, such as EEDI, EEXI and CII and EU's decision to include all ships over 5,000 GT in its emission trading scheme EU ETS as from 1 January 2024. These changes have a particular impact on vessels operating in ice-infested waters within the EU. This applies especially to ro-ro and ro-pax vessels.

The real value of the provided WNRB funding has decreased substantially since start, influencing the shift in interest from oceanography and metrology to more technical challenges, on higher TRL-levels and closer to commercial usage.

The WNRB funding has, in real terms, been cut in half since 1972. An increase of 50% (or more) is proposed to restore the actual level of funding at least to where it was in the 1980s. This would raise the annual funding to €300,000. We strongly believe, that there are plenty of winter navigation related research tasks with very high value-for-money ratios.

The importance of winter navigation is increasing for Finland and Sweden, and it is safe to say that the WNRB has been well managed. Given the special importance of winter navigation for Finland and Sweden, the 1972 agreement was farsighted indeed.

[17] The titles of the reports are shown in a chronological order in **Appendix 2**, where a link to full reports is given

Appendices

Appendix 1 Thematic division in the 2023 Call. Source: [Traficom]

General topics of the 2023 Call

This Call is aimed at projects that address one or more of the following areas:

Meteorological research

- o research related to marine meteorology in winter conditions
- o research related to ice formation
- o climatologic research related to the aforementioned topics
- o development of forecasting and modelling
- o development of new tools for presentation of satellite images

Oceanographic research

- o research related to ice conditions at sea or sea water temperature
- o sea currents, sea water level and sea waves in winter
- o climatologic research related to the aforementioned topics
- o development of forecasting and modelling
- o development of new tools for presentation of satellite images

Technical research

- o structural design of hulls of ice-going ships
- o structural design of propulsion machinery of ice-going ships
- o development of minimum engine power regulations for merchant ships
- o winterization of merchant ships

Winter navigation

- o research on the effectiveness and costs of icebreaker assistance
- o research on winter traffic flows in the Baltic Sea area, including efficiency, safety, environmental impact and economics of winter navigation.

Specific thematic research topic for 2023

Specific research topic 1: Winter navigation system energy efficiency

- o Investigation based on one or several case studies to find balance between trends of merchant fleet assistance needs and icebreaker resources to achieve minimum system emissions by optimizing total winter navigation system fuel economy, maintaining present service level.

Specific research topic 2: Digitalization and winter navigation

- o Study on digital maturity of today's merchant fleet for digitalization of services and means for information exchange between vessels and icebreakers and other actors.

Specific research topic 3: FSICR status with regards to future changes of the FSICR and guidelines

- o A study on the challenges and advantages and status of the FSICR from the point of views of all the different stakeholders' in connection with the rules and guidelines.

Appendix 2 Reports published by the Winter Navigation Research Board in chronological order by title. The publication year refers to the year, when a report was published by the WNRB

Note that the publication year by the WNRB does not necessarily correspond to the period when an individual study was approved for funding, conducted or finalized. There was a particularly long gap of publication in the 1990s and from year 2020 prior to year 2014.

All the reports can be accessed here.

Reports published during the 1970s (all in all 36 with the sub-reports)

No 1 Haviskonferens 1972

No 2 Vintersjöfart i Bottenhavet

No 3 Isskador på fartyg i Östersjön, Bottenhavet och Bottenviken

No 4 Propellerproblem

No 5 Fartygs framdrivningsmotstånd i is

No 6 Vintersjöfart med stora fartyg i Bottenviken

No 7 Vintersjöfart i Bottenviken

No 8 Havisundersökningen i Bottenviken vintern 1947

No 9 Kartering av ytvattentemperaturen i vattnen runt Sverige

No 10 Experiments on remote sensing of sea ice using a microwave radiometer

No 11 Bottenvikens stålfyrar – hållfasthetsanalys och förbättringsförslag

No 12 Formation and structure of ice ridges in the Baltic

No 13 Calculation of ice drift in the Bothnian Bay and the Quark

No 14 A narrow beam sonar to measure the submarine profile of an ice ridge

No 15 The average surface temperature in the autumn and the early winter on the Gulf of Bothnia, the northern Baltic Sea and the Gulf of Finland

No 16_1 Sea ice -75 Programme

No 16_2 Sea ice -75 Ground truth report

No 16_3 Sea ice -75 Ice detection by SLAR

No 16_4 Sea ice -75 Analysis of SLAR data

No 16_5 Sea ice -75 FLAR, ODAR, ship's radar

No 16_6 Sea ice -75 IR-scanner results

No 16_7 Sea ice -75 Radar altimeter results

No 16_8 Sea ice -75 Dynamical report

No 16_9 Sea Ice-75 Summary report

No 17 The shape and size of ice ridges in the Baltic according to measurements and calculations

No 18 A numerical model for forecasting the ice motion in the Bay and Sea of Bothnia

No 19 Creep of fresh water ice at high homologous temperatures

No 20 Economics of winter navigation in the northern part of the Gulf of Bothnia

No 21 Measurement and analysis of ice-induced stresses in the shell of an icebreaker

No 22 Measurements of physical characteristics of ridges on April 14 and 15, 1977[18]

No 23 Ice accretion on ships with special emphasis on Baltic conditions

No 24 Presentation of sea ice ridges in general and physical characteristics of Baltic ridges for ship resistance calculations

No 25 On conditions for the rise of self-excited ice-induced autonomous oscillations in slender marine pile structures

No 26 Some results from a joint Swedish-Finnish Sea Ice Experiment, March 1977

No 27 On plastic design of an ice-strengthened frame

No 28 Long term measurements of ice pressure and ice-induced stresses on the icebreaker Sisu in winter 1978

Reports published during the 1980s (total of 19 reports)

No 29 On the drift and deformation of sea ice fields in the Bothnian Bay

No 30 A sensitivity analysis of steady free floating ice

No 31 A study of the large scale cooling in the Bay of Bothnia

No 32 Statistical features of sea ice ridging in the Gulf of Bothnia

No 33 Performance of marine propellers in ice-clogged channels

No 34 BASIS -A data bank for Baltic Sea ice and sea surface temperatures

No 35 Vertical mixing and restratification in the Bay of Bothnia during cooling

No 36 Formation, thickness and stability of fast ice along the Finnish coast

No 37 Dynamic loads and response of icebreaker Sisu during continuous icebreaking

No 38 Undersökning av skrovformens inverkan på propellerns isbelastning samt rännans renhetsgrad genom modellförsök i is

No 39 A forecast model for water cooling in the Gulf of Bothnia and lake Vänern

No 40 The atmospheric boundary layer over the Bothnian Bay; a review of work on momentum transfer and wind structure

No 41 An investigation of the crystal structure of sea ice in the Bothnian Bay

[18] **Only the title of Report 22 is available in the Traficom listing; Report 24 was stored in its stead**

No 42 Long-term measurements of ice induced loads on the propulsion machinery of product tanker Sotka

No 43 Result and statistical analysis of ice load measurements on board icebreaker Sisu in winters 1979 to 1985

No 44 Isförhållandena i Sveriges södra och västra farvatten

No 45 BEBERS (Bothnian Experiment in Preparation for ERS-1)

No 46 BEBERS -88 -Experiment plan

No 47 Results of long-term ice load measurements on board chemical tanker Kemira in the Baltic Sea during the winters 1985 to 1988

Reports published during the 1990s (total of 5 reports)

No 48 Sea ice properties studied from the icebreaker Tor during BEBERS -88

No 49 Real-time modelling and forecasting of temperatures in the Baltic Sea

No 50 Damage statistics of ice-strengthened ships in the Baltic Sea 1984-1987

No 51 Baltic Experiment for ERS-1

No 52 Performance of merchant vessels in ice in the Baltic

Reports published in 2000 to 2009 (total of 48 reports)

No 53 On the power requirement in the Finnish-Swedish ice class rules

No 54 Incidents And Accidents 2003

No 55 The Observations of the Performance of Small Tonnage in Ice

No 56 Technology for the assistance of large tankers in heavy ice

No 57 A preliminary risk analysis

No 58 Traffic Restrictions to Finnish and Swedish Ports

No 59 Ships in Compressive Ice

No 60 Definition of the new Ice Class IA Super +

No 61 Långa tidsserier och klimat 2003-2007

No 62 AIS-data för stora tankfartyg i Finska viken - Vintern 2006

No 63 Utveckling av prototyp för isdriftsbojar, 2007

No 64 Improved sea-ice monitoring for the Baltic Sea, 2007

No 65 Icemechanics and shipping in ice-infested waters

No 66 Analysis of the influence of the channel profile

No 67 Factors influencing the power requirement in the FSICR

No 68 VoyStat - Analysis of ship travel times during winter months 2006 and 2007

No 69 Variational data assimilation of sea ice in the Baltic sea - Year 1

No 70 Plastic deformation simulations of propeller blades

No 71 Design point in ice class rules

No 72 The influence of ship characteristics on icebreaker demand

No 73 An experimental study on the effect of speed on the ice resistance of a ship - Phase I

No 74 An experimental study on the effect of speed on the ice resistance of a ship - Phase II

No 75 Comparison of ice load models for azimuthing thruster ice load calculation

No 76 Observations of Ship Ice Performance in the Baltic Winter 2011

No 77 Impact of the proposed energy efficiency regulation on Baltic tankers and bulkers

No 78 Possibilities to decrease the attained EEDI of the Finnish merchant ships

No 79 Improving model thermodynamics used in medium-range Baltic Sea ice forecasts

No 80 A feasibility study of a trafficability ice chart service

No 81 Variational data assimilation of sea ice in the Baltic sea - 2nd and final year

No 82 Analysis of requirements for a new generation ice breaker for the Baltic

No 83 Energy efficiency of the Baltic winter navigation system

No 84 Observations of ship ice performance in the Baltic

No 85 IBNext - Future needs and development of the icebreaker information system - a pre-study

No 86 Breaking the universal language barrier

No 87 Azimuthing thruster ice load calculation

No 88 EEDI and Finnish-Swedish ice class rules

No 89 ESAR - Enchanced SAR imagery for the Baltic Sea winter navigation

No 90 Relevance of Charpy-V impact criteria for nodular cast iron

No 91 Azimuthing thruster ice load calculation and simplified ice contact load formulation

No 92 New methods for measuring ice ridges and ice channels in full-scale

No 93 Ship-ice interaction in a channel

No 94 Notch towing operations

No 95 Inventory for ice performance of Baltic IA Super Traffic 2007-2016

No 96 Azimuthing thruster ice load distribution studies

No 97 Dynamic response of propulsion shaft line systems to propeller ice torque excitation

No 98 Improved satellite images using innovative interaction

No 99 Validation of the preliminary assessment regarding the operational restrictions of ships ice-strenghtened in accordance with the Finnish-Swedish ice classes when sailing in ice conditions in Polar waters

Reports number 100 and 101 do not exist due to an error in numbering

No 102 Brash ice channel research

Reports published in the 2020s (total of 24 reports up until September 2023)

No 103 Capability of Energy Efficient Ships for Winter Operations on the Bothnian Bay

No 104 ICEEDI Power requirements according to FSIC rules and EEDI compliance

No 105 PREEDICT -EEDI Power Correction Factors FJ for Ice Class Ships

No 106 NowIce – predicting transit times of ships in winter navigation

No 107 Channel Resistance in Full Scale and in Model Scale

No 108 Effect of the FSICR to Propeller Efficiency

No 109 Improving the Efficient Usage of the Icebreakers in the Baltic Sea

No 110 Use of Drones in icebreaker operations – a feasibility study

No 111 Study on the Current Winter Navigation Challenges Related to EEDI regulations at the Bay of Bothnia

No 112 Holistic Simulation-based Assessment of the Operational Performance of the Finnish-Swedish Winter Navigation System

No 113 Using Drones in icebreaker operations in the Baltic Sea - a demonstration

No 114 EEDI and the need for icebreaker assistance

No 115 Correlation tests with MT Uikku in three model brash ice channels

No 116 Towing in ice during escort

No 117 Granular ice simulation for Bay of Bothnia

No 118 EEDI and the need for icebreaker assistance II

No 119 Monitoring of ships under assistance

No 121 Channel widening by propeller flow

No 122 Propeller shaft response to ice exitation

No 123 Baltic forecast improvements using remote sensing data

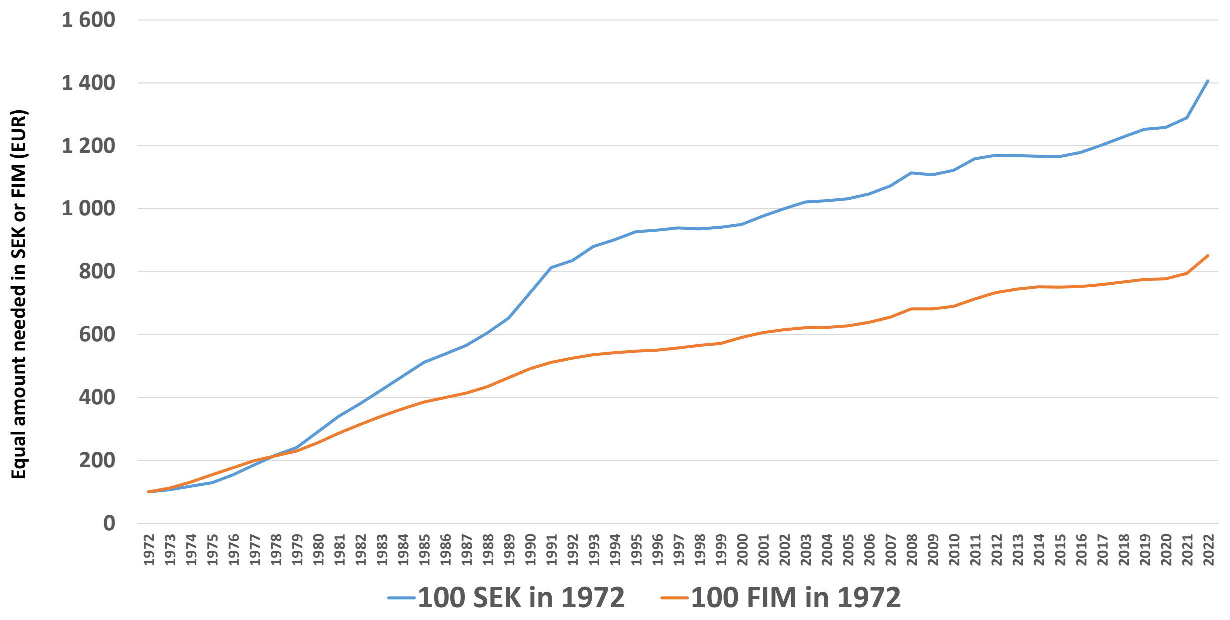
No 124 AI Based simulation for intelligent ice navigation

No 125 Direct calculations methods for ice strengthened hulls in the Finnish-Swedish ice class rules

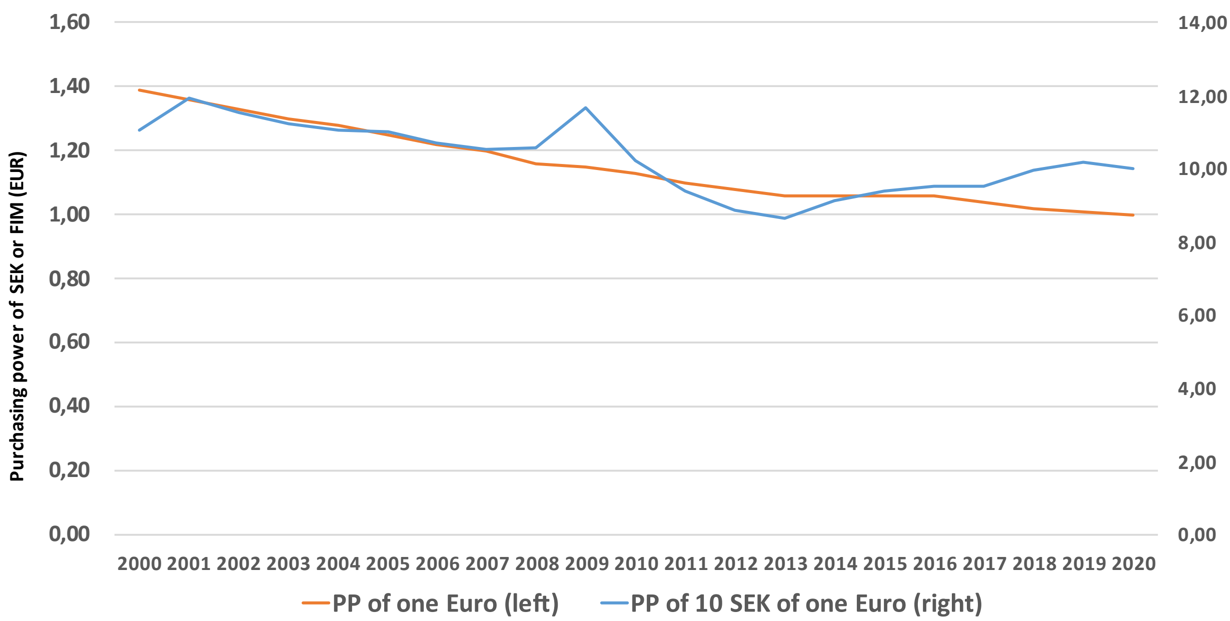
No 126 Baltic forecast improvements using remote sensing data-2(Baltic fire-2)

No 127 Research on merchant vessel's ability to provide sufficient thrust at low icebreaking speeds

Appendix 3 Purchasing power of 100 SEK and FIM (EUR) since 1972

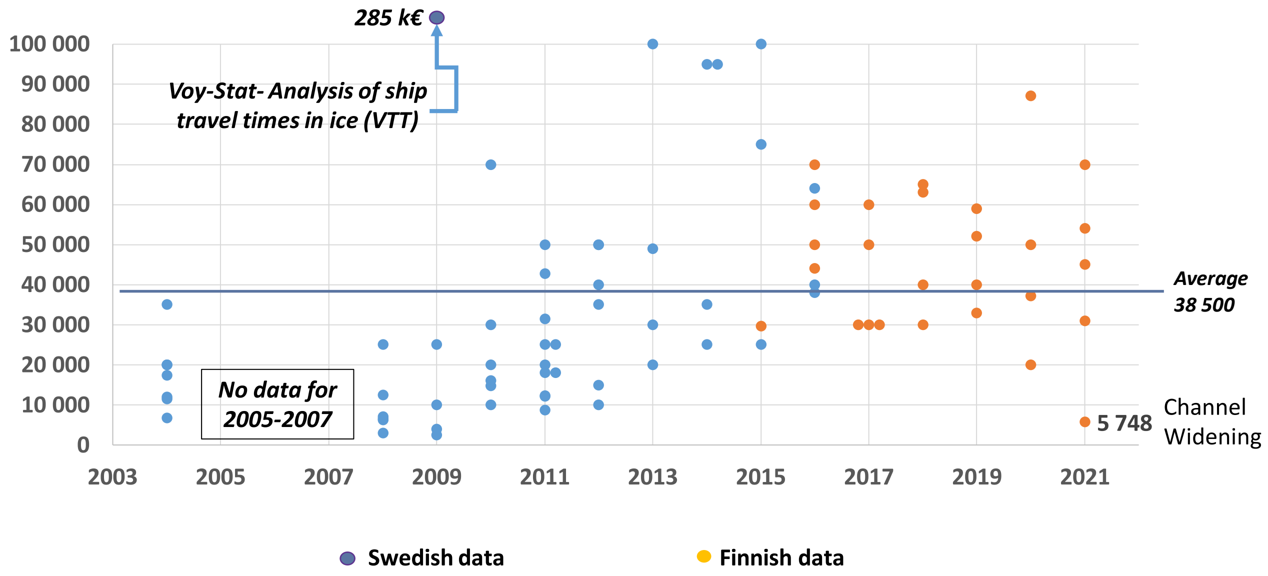


Currency conversion rates based on data from ECB, Bank of Finland and Sveriges Riksbank



Currency conversion rates based on data from ECB, Bank of Finland and Sveriges Riksbank

Appendix 4 Funding of WNRB projects in 2004 and 2008-2021, by decision year



Appendix 5 WNRB reports by theme and decade

Division of the 120 reports by sub themes and decades	Total	1970s and 1980s	1990s and 2000s	2010s and 2020s
Technical	**47**	**10**	**5**	**32**
Design of propulsion machinery	15			
Structural design of hulls	12			
EEDI, EEXI, CII	9			
Winterization of merchant ships	8			
Minimum engine power regulations	3			
Oceanographic	**46**	**27**	**4**	**15**
Ice conditions at sea or sea water temperature	24			
Forecasting and modelling	14			
Sea currents, water level and waves in winter	4			
Climatologic research on above	2			
New tools for presentation of satellite images	2			
Winter navigation	**18**	**5**	**4**	**9**
Winter traffic flows in the Baltic Sea area, incl. efficiency, safety, environmental impact and economics	13			
Effectiveness and costs of IB assistance	5			
Meteorological	**6**	**3**	**1**	**2**
Forecasting and modelling	3			
Marine meteorology, ice formation, climatology	3			
Other (symposium reports)	**3**	**2**	**1**	**0**

Note:

Especially several ice condition and ice formation reports could be labelled both under Oceanographic and/or Meteorological headings.

The division by themes is therefore indicative.

Appendix 6 Income and costs of icebreaking operations in Sweden (in SEK million). Source: Swedish Maritime Administration annual report (Årsredovisning) for 2022

	2022	2021	2020
Direct operating income		**in SEK million**	
Allowance	40	-	-
Other external income	66	85	58
Total direct operating income	**106**	**85**	**58**
Direct operating costs			
Personnel costs	-28	-25	-33
Other external costs	-314	-319	-274
Depreciation	-21	-21	-17
Total direct operating cost	**-363**	**-365**	**-324**
Profit before indirect operating items	-257	-280	-266
Indirect operating costs	4	8	4
Indirect operating income	-34	-39	-42
Operating result	-287	-311	-304
SEK to EUR at the end of the year	*0,090*	*0,097*	*0,100*