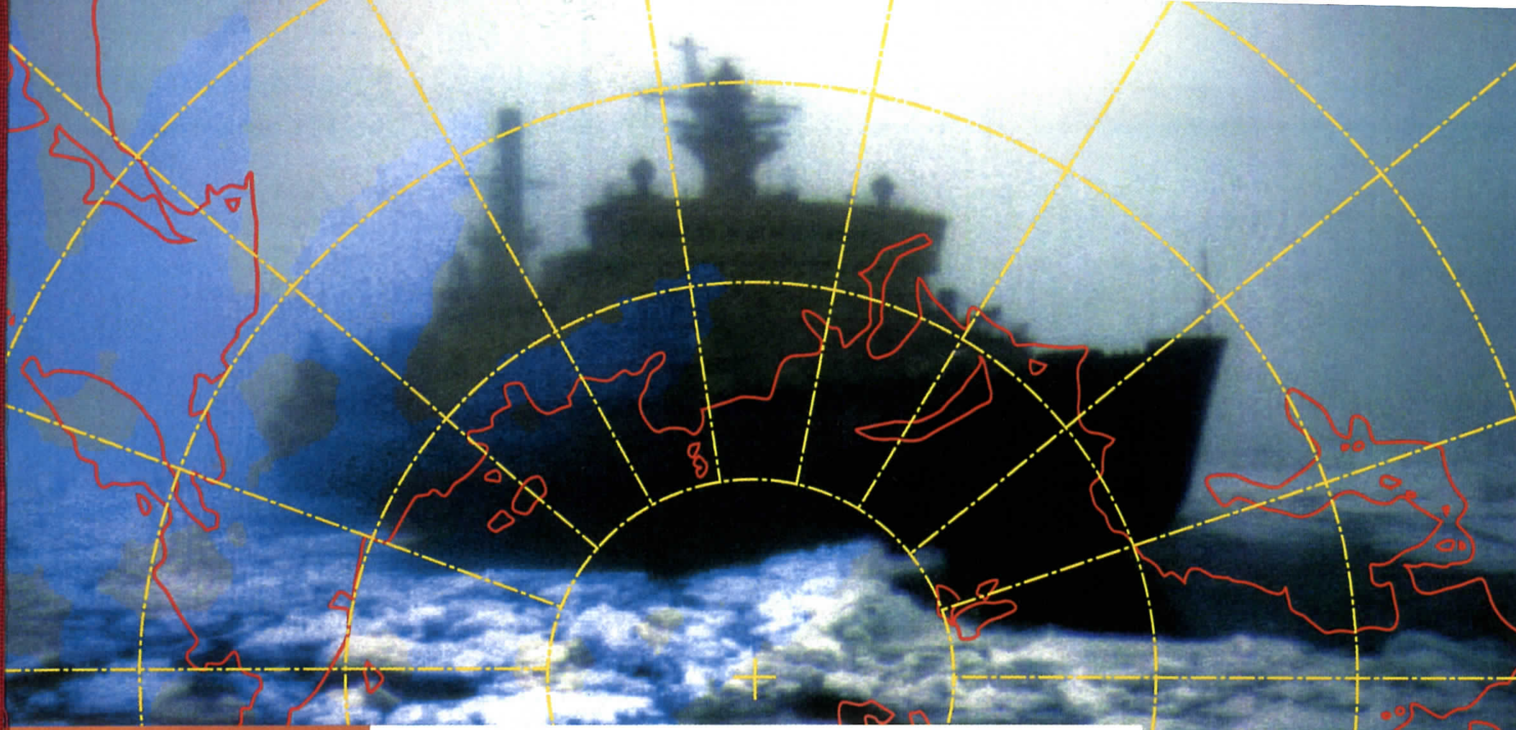
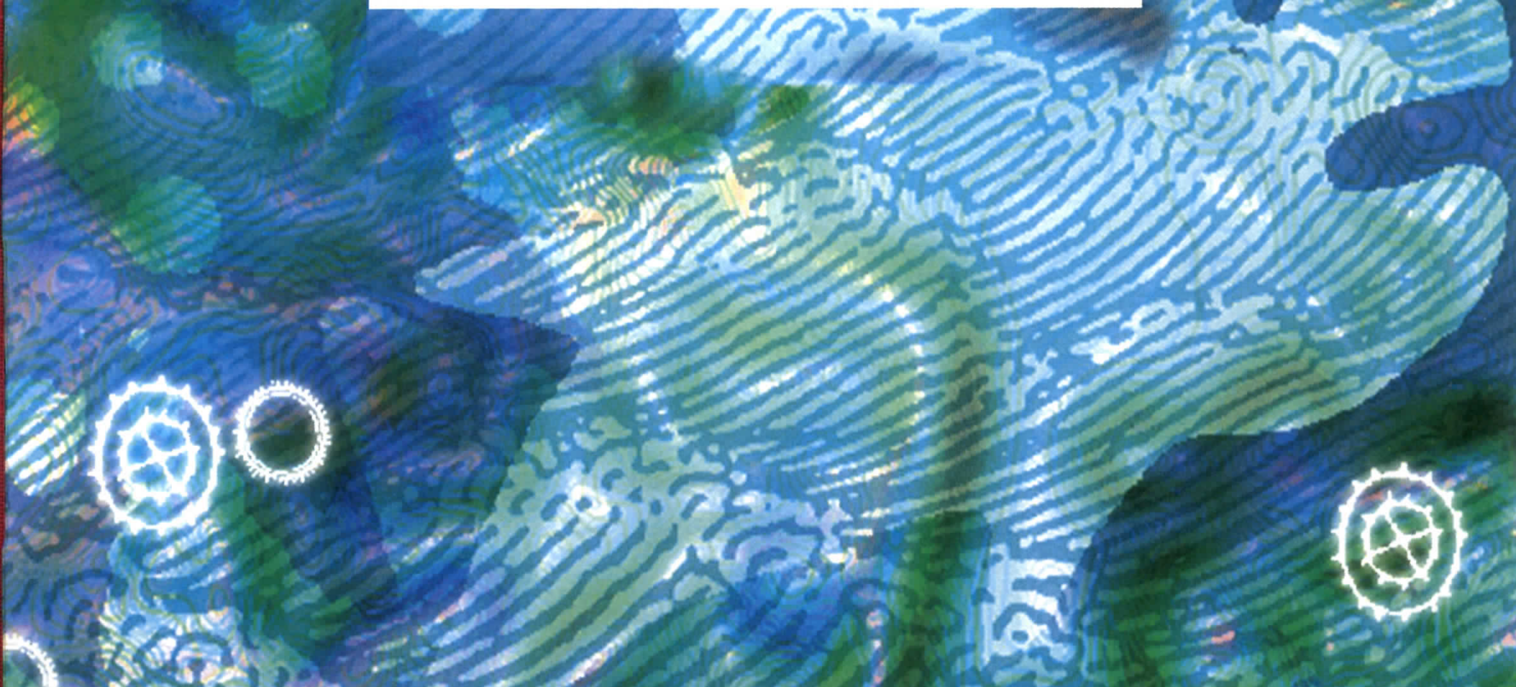


INSROP WORKING PAPER
NO. 143 - 1999, III.07.8

Scenarios of Seasonal and Year-Round Navigation along the Northern Sea Route

By Y.M. Ivanov, N.A. Isakov, A.N. Yakovlev, V.P. Smirnov, A.E. Nikulin and E.G. Logvinovich



INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship and Ocean Foundation, Japan

International Northern Sea Route Programme (INSROP)

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Ship & Ocean Foundation, Japan

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Sub-programme III:	Trade and Commercial Shipping Aspects
Project III.07.8:	Scenarios of Seasonal and Year-Round Navigation along the Northern Sea Route
Supervisor:	Yuri M. Ivanov, CNIIMF
Title:	**Scenarios of Seasonal and Year-Round Navigation along the Northern Sea Route**
Authors:	**Y.M. Ivanov, N.A. Isakov, A.N. Yakovlev, V.P. Smirnov, A.E. Nikulin and E.G. Logvinovich**
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Date:	24 March 1999
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What is an INSROP Working Paper and how to handle it:

This publication forms part of a Working Paper series from the **International Northern Sea Route Programme - INSROP**. This Working Paper has been evaluated by a reviewer and can be circulated for comments both within and outside the INSROP team, as well as be published in parallel by the researching institution. A Working Paper will in some cases be the final documentation of a technical part of a project, and it can also sometimes be published as part of a more comprehensive INSROP Report. For any comments, please contact the authors of this Working Paper.

FOREWORD - INSROP WORKING PAPER

INSROP is a five-year multidisciplinary and multilateral research programme, the main phase of which commenced in June 1993. The three principal cooperating partners are **Central Marine Research & Design Institute (CNIIMF)**, St. Petersburg, Russia; **Ship and Ocean Foundation (SOF)**, Tokyo, Japan; and ***Fridtjof* Nansen Institute (FNI)**, Lysaker, Norway. The INSROP Secretariat is shared between CNIIMF and FNI and is located at FNI.

INSROP is split into four main projects: 1) Natural Conditions and Ice Navigation; 2) Environmental Factors; 3) Trade and Commercial Shipping Aspects of the NSR; and 4) Political, Legal and Strategic Factors. The aim of INSROP is to build up a knowledge base adequate to provide a foundation for long-term planning and decision-making by state agencies as well as private companies etc., for purposes of promoting rational decisionmaking concerning the use of the Northern Sea Route for transit and regional development.

INSROP is a direct result of the normalization of the international situation and the Murmansk initiatives of the former Soviet Union in 1987, when the readiness of the USSR to open the NSR for international shipping was officially declared. The Murmansk Initiatives enabled the continuation, expansion and intensification of traditional collaboration between the states in the Arctic, including safety and efficiency of shipping. Russia, being the successor state to the USSR, supports the Murmansk Initiatives. The initiatives stimulated contact and cooperation between CNIIMF and FNI in 1988 and resulted in a pilot study of the NSR in 1991. In 1992 SOF entered INSROP as a third partner on an equal basis with CNIIMF and FNI.

The complete series of publications may be obtained from the Fridtjof Nansen Institute.

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SUMMARY

The aim of the project is to make scenarios of seasonal (summer and prolonged) and year-round navigation along navigable passages of the Northern Sea Route (NSR) and prepare recommendations on the selection of rational navigating routes to assess commercial efficiency of the following kinds of transportation:

- regional transportation in Western Arctic area as a supply of the equipment and exports of power raw materials (oil, gas, coal), metals, fertilizers and timber from North -Western regions of Russia;
- regional transportation in Eastern Arctic area as an importation of the equipment and supply cargo, fuel and foodstuffs and exports of timber and coal from North -Eastern regions of Russia;
- NSR transportation of transit containerized and bulk cargoes for two routes - deepwater northern (high latitudinal) and shallow south (coastal) with possible use of the river Yenisey river and railway from Yakutsk.

The suggested scenarios of seasonal and year-round navigation may serve as a basis for modelling of shipping as stipulated in the project WP8

Key personnel:

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CONTENTS

TERMS AND DEFINITIONS

Navigation scenario	Description of the process of shipping along the NSR in terms of speed and time required for ships of particular sizes to pass through rated stretches (legs) under light, medium and heavy conditions of navigation.
LL1	Ice-class of icebreakers designed for all kinds of icebreaker operations in the Arctic seas in any season of the year including operations in unbroken ice fields of more than 2.0 m thick.
LL2	Ice-class of icebreakers designed for all kinds of icebreaker operations in the Arctic seas in summer season including operations in unbroken ice fields of less than 2.0 m thick.
LL3	Ice-class of icebreakers designed for all kinds of icebreaker operations in the non-Arctic seas in winter season including operation in unbroken ice fields up to 1.5 m thick.
ULA	Class of ice-strengthened vessels capable of unassisted sailing in Arctic ice conditions in summer-autumn seasons and with icebreaker leading in winter season.
UL	Class of ice-strengthened vessels capable of unassisted sailing in the Arctic in light ice conditions in summer-autumn seasons and in all seasons in freezing waters outside the Arctic seas.
Ice traffic ability	Capability of a vessel to effect non-stop sailing at a speed of 1.5-2.0 knots in unbroken ice fields of a limited thickness.
Compactness of ice	Navigational characteristic of ice determined by its stable breaking (given in numbers from 1 to 10).
Ice sailing	Passing through stretches of seaways covered with compact ice characterized by concentration number of more than 3.
Convoy	Group of 2-3 transport vessels, which travel together in the wake of the leading icebreaker along the canal made by it or along clearings in ice.
Tandem	Method of icebreaker leading when the bows of the towed vessel are put into the stern cut-out of the icebreaker and kept there at short stay.
NSR	The Northern Sea Route. The Russian national transport seaway in the Arctic. Its limits are: the western entrances to the Novaya Zemlya straits and the meridian leading northward of cape Zhelaniya – in the west, and the Bering strait along the latitude 66° N and the meridian 168°58'37"W - in the east. The NSR includes navigable sea routes in ice leading through the Russian internal marine waters, territorial sea and the Russian Economic zone.
Western part of the NSR	The part from the Novaya Zemlya straits to the meridian 125°E (up to the mouth of the river Lena from westward).
Eastern part of the NSR	The part from the meridian 125°E to the Bering strait (eastward from the mouth of the river Lena).
Change in the draft	($-\Delta T$, $+\Delta T$) which the ship would have in open water for the accepted loading condition and various speeds as a result of transfer from open into ice water area or vice versa. This change in draft hereafter is referred to as water-ice-draft change.

INTRODUCTION

Scenarios of seasonal and year-round navigation along the Northern Sea Route include the problems of regional shipping organization and transit sailing in various calendar periods with allowance for the development of ice conditions and traditional cargo traffic in the Arctic.

The results of a research into potential transit and regional cargo-flows are based on the Federal programs of the development of the Russian northern regions along the NSR. A detailed treatment of the results is given in such special projects as WP3, III.01.5 and III.07.7 of 1997-1998. These projects continue the research made in phase 1 of INSROP in projects: III.01.1, III.01.3, III.02.2, III.07.3 and III.07.4.

Each scenario is based on long-term experience in organization of Arctic navigation, analysis of documentary and statistical information concerning Arctic shipping. The above scientific approach to the problem proves the importance of such experience for methods of processing and utilization of relevant information in Arctic navigation.

Dr. Smirnov suggests analytical calculations and a system of coefficients, which take account of speeds of large transport vessels proceeding unassisted in ice or moving in convoy under icebreaker escort.

It seems to be extremely important that the water-ice -draft change experienced by transport vessels sailing in ice over shallow depths was taken into account in the research carried out by V. Smirnov. Special ice tests and registration of the above change in each vessel's ice passport enable her master to correctly determine the vessel's draft when proceeding through ice fields in shallow waters and thus ensure safe sailing.

Project III.07.8 presents a model of creating scenarios of seasonal and year-round navigation along the NSR, which is based on information coming from the systems of forecasts and warnings on changes in navigational situation.

According to the plan for 1998, provision has been made for study of ship ice and navigational observations to be made under Project III.07.8. The necessity for the above scenarios stems from the fact that the shipboard observations and communication facilities provided for describing ice and navigational conditions of shipping along the NSR have not been taken into account in relevant normative documents covering organization of ship ice and navigational observations.

Navigation scenarios are worked out for the routes shown in project WP1 with regard to types of navigation and ice conditions, which characteristics and definitions are stated in the "Guide to Navigation through the Northern Sea Route"[1].

Technical means include the main vessels of Arctic sailing and icebreakers which have been in service for the last 10-15 years. Specifications and operating characteristics of the vessels in point appear to be close to the estimated ones, which have been determined in the task pre-set in project WP1 and may have but small errors (Appendix 1).

The characteristics of the hydrometeorological system of servicing the NSR worked out in the Arctic and Antarctic Research Institute (AARI) and conditions under which the services are rendered to their users are shown in Appendix 2.

The suggested scenarios of seasonal and year-round navigation may serve as a basis for simulating of shipping as stipulated in project WP8.

1. CONTEMPORARY STATE OF NSR NAVIGATION PLANING PROCESS

The planning of navigation along the NSR is being based on the Decrees of the *RF* Government and annual plans of Arctic navigation, prepared by shipping companies.

Description of the planning of navigation along the NSR include:

- directions and volumes of cargo-flows for the period of navigation;
- calculations to determine the required tonnage and types of cargo vessels for the period of navigation;
- preliminary assessment of navigation types for spring, summer and autumn periods; commencement and end of icebreaker sailing, mass icebreaker leading and unassisted sailing periods;

positioning of icebreakers along the NSR seaways with allowance for ice conditions.

1.1. Directions and Volumes of Cargo-Flows for the Period of Navigation

The directions of cargo-flows in case of regional and transit freight traffic along the NSR are shown in Fig. 1. The formation of annual cargo volumes and the procedure of their transportation to the Extreme North regions are carried out in compliance with the Decrees of the Russian Federation (RF) Government [2, 3].

Ministries, departments, enterprises and other organizations responsible for the delivery of goods to the Extreme North regions shall submit annual plans (detailed in quarters) of cargo transportation to the Ministry of Railway Communication, the Merchant Marine Service (Rosmorflot) and the Merchant River Service (Rosrechflot) of the Ministry of Transport of the RF not later than 15 November of the year preceding the year of delivery.

The Ministry of Railway Communication, the Rosmorflot and the Rosrechflot determine an annual volume of delivery of goods to the regions of the Extreme North not later than 1 January of the year of delivery. They submit corresponding data to the Goskomsever of the RF and to relevant ministries and departments concerned informing them of annual volumes of cargo transportation (detailed in quarters) to the above region not later than 15 January of the year of delivery [2].

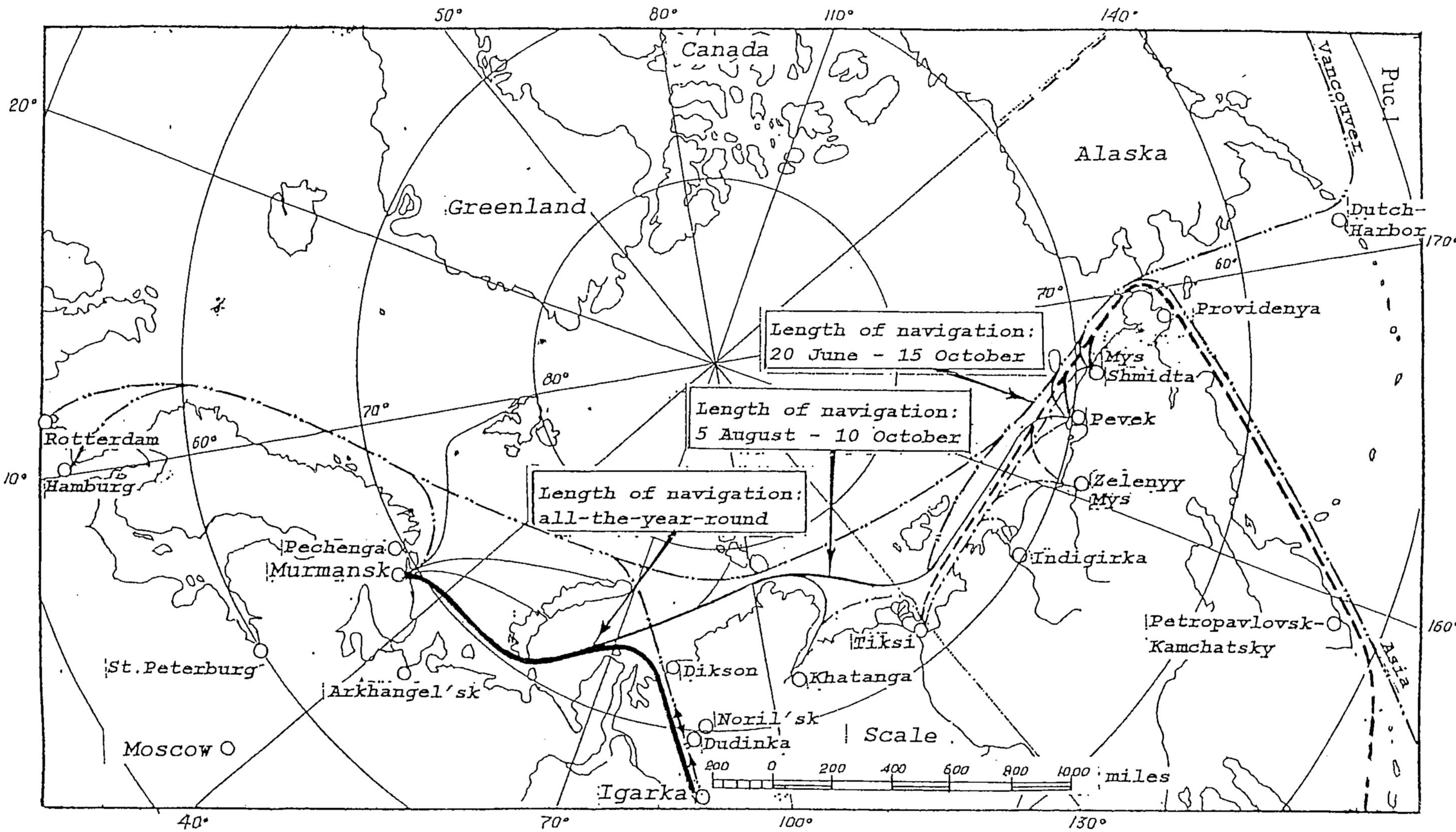

Fig 1. Main directions of cargo transportation along the Norhern Sea Route

Delivery of cabotage cargo from West
Delivery of cabotage cargo from East
Intra-Arctic transportation of cabotage cargo
Transit, export and import transportation of cargo

The subjects of the RF, Goskomsever of the RF, Ministry of Fuel and Power Engineering of the RF with participation of the Ministry of Economy of the RF estimate volumes of delivery of oil, oil products to the North regions with limited navigation periods (3).

By the commencement of navigation the ministries, departments, enterprises and other organizations responsible for delivery of goods to the Extreme North regions, shall accumulate main kinds of goods and oil-products in the assortment and volumes as approved by the Goskomsever of the RF [2]. The potential volume of transit traffic along the NSR by chartered Russian and foreign ships is established by the Murmansk and Far East Shipping companies together with the Administration of the NSR.

1.2. Estimation of Required Tonnage and Types of Cargo Vessels for the Period of Navigation

The main volume of cargo transportation along the NSR is effected by ULA class vessels (approximately 20 in number) and UL class vessels (approximately 100 in number).

Due to twofold reduction in the coastal freight traffic the total tonnage of the Arctic merchant fleet is not fully used to satisfy the existing transport needs, that is, there is a tonnage reserve. Generally, the transportation is provided by the vessels of the Murmansk Shipping Company (over 60%). Delivery of oil products and fuels to the West region of the Arctic is effected by foreign tankers (10-12 in number), and to the East region - by the tankers of the Far East Shipping Co. (FESCO).

Ten vessels carry out transit cargo transportation. Estimation of required tonnage and types of vessels for the period of navigation are made by the shipping companies with due regard for annual volumes of transportation to certain regions.

1.3. Preliminary Assessment of Ice Conditions for the Period of Navigation

Preliminary assessment of ice conditions for the period of navigation includes the assessment of:

- types of difficulties likely to be met during spring, summer and autumn periods;
- times of commencement and end of icebreaker sailing, mass icebreaker leading and unassisted sailing;

- expected time required to effect icebreaker leading along the NSR.

The preliminary assessment of ice navigation is effected by the State Scientific Centre of the RF - the Arctic and Antarctic Scientific Research Institute (Ice Centre "North", Fig. 2) [4].

Using mathematical methods, computer simulation and long-term data on Arctic sea ice the Ice Centre "North" carries out computer processing of current hydrometeorological information and supplies the users with the forecasts of ice situation and navigational recommendations for the forthcoming period of 6 months (Appendix 2).

The Decree of the RF Government [2] sets the times of opening and closing of sea and river ports for reception and transhipment of cargoes directed to the regions of the Extreme North.

1.4. Positioning of Icebreakers along the NSR Depending on Ice Conditions

6 atomic and 7 diesel-engine liner icebreakers are in service on the NSR. The number of icebreakers and reliability of sailing allow us to meet the requirements of the Arctic shipping. The icebreakers of the Murmansk Shipping Co. (MSC) carry out most icebreaker leading operations (6 atomic and 3 diesel-engine icebreakers). The geographical area of the MSC icebreaker leading activities extends to the east as far as the port of Cape Shmidta.

Diesel-engine icebreakers of the Far East Shipping Co. (4 in number) carry out icebreaker leading in the eastern part of the NSR as far as the port of Tiksi. In the periods of heavy ice conditions the icebreakers of the Murmansk Shipping Co. take part in icebreaker leading in the eastern part of the NSR too.

Total time of icebreaker operations in prolonged periods of navigation (winter, spring, autumn – 1080 icebreaker-days) considerably exceeds the time of summer operations (795 icebreaker-days).

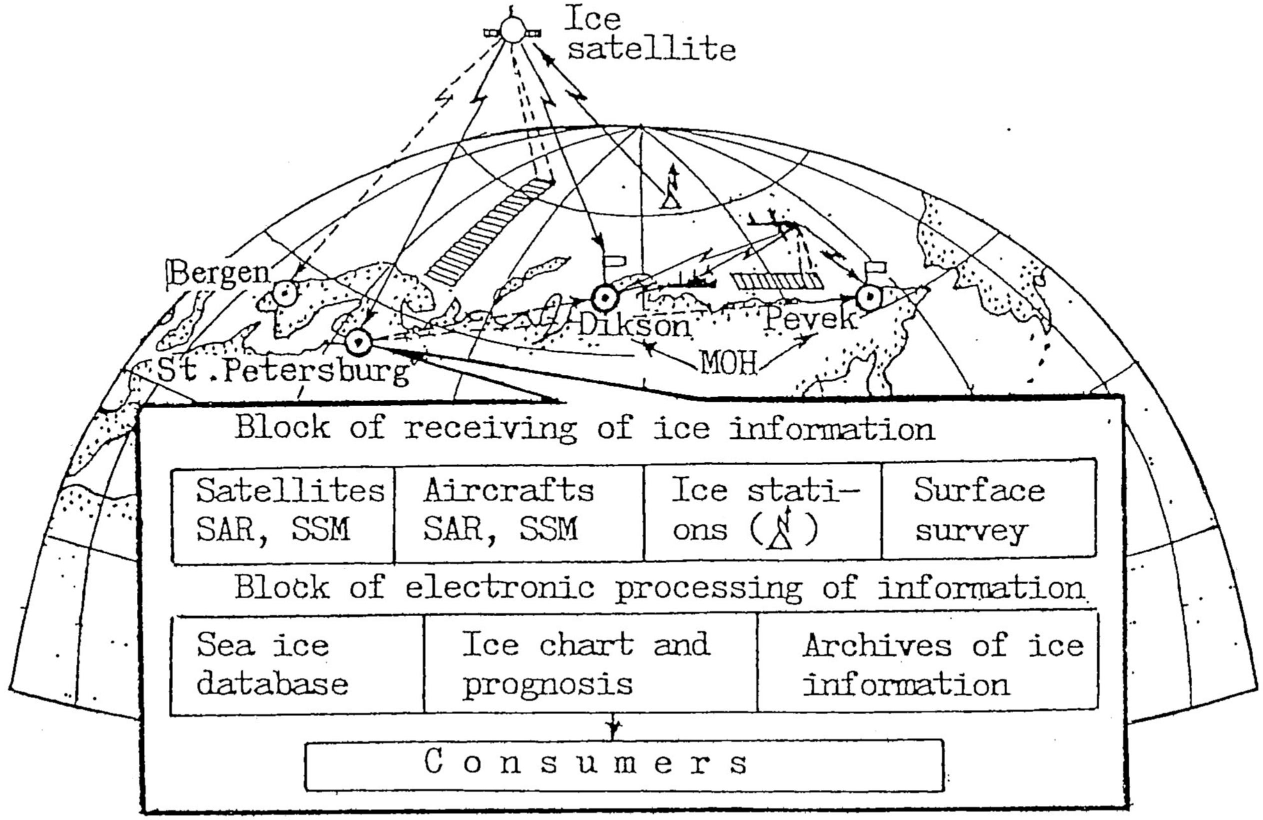

Fig. 2. Russian Ice Centre "North"

SAR - synthetic apertura radar
SSM - special sensor microwave
MOH - Marine Operations Headquarter

Positioning of icebreakers along the NSR in the periods of summer and autumn-winter navigation (July-December) depends on ice conditions, the engine-power of icebreakers and the number and types of vessels requiring icebreaker leading.

Relevant calculations are made in accordance with the methods [5] in which the following criterion of leading capability of icebreakers (N) has been used:

$$N = V_{cy} * T * n / 2 * S,$$

where:

- V_{cy} - speed of icebreaker leading convoy;
- T - period of operation in hours;
- n - number of ships in convoy;
- S - length of an ice stretch in nautical miles.

Period of operation T and length of stretch S are constants, while speed V_{cy} and number of vessels in convoy n are variables. Speeds of ships moving in convoy under icebreaker assistance in ice conditions are established by the leader and based on the speed of the most slow-running ship in the group.

This rule is determined by the ice navigation tactics and defined by the documents regulating safety of navigation along the NSR.

The table given in the report shows ship speeds corresponding to types of ships under consideration. The data have been taken from the records concerning fleet operation of the Murmansk Shipping Company by navigational seasons and ice conditions from 1989 to 1993.

The system of speed coefficients suggested in the work is a result of processing of actual observation materials, made by the mathematical statistics techniques.

The design ratios given with 95 % probability are in excellent agreement with the actual data on movement of ships and convoys under various ice conditions during the Arctic navigation periods.

Fig. 3 shows the dynamics of changes in icebreaker leading capability (N) for a heavy seaway stretch of 100 miles long and the period of icebreaker operation within the stretch for 30 days (720 hours) in dependence of the speed of leading and number of vessels in convoy.

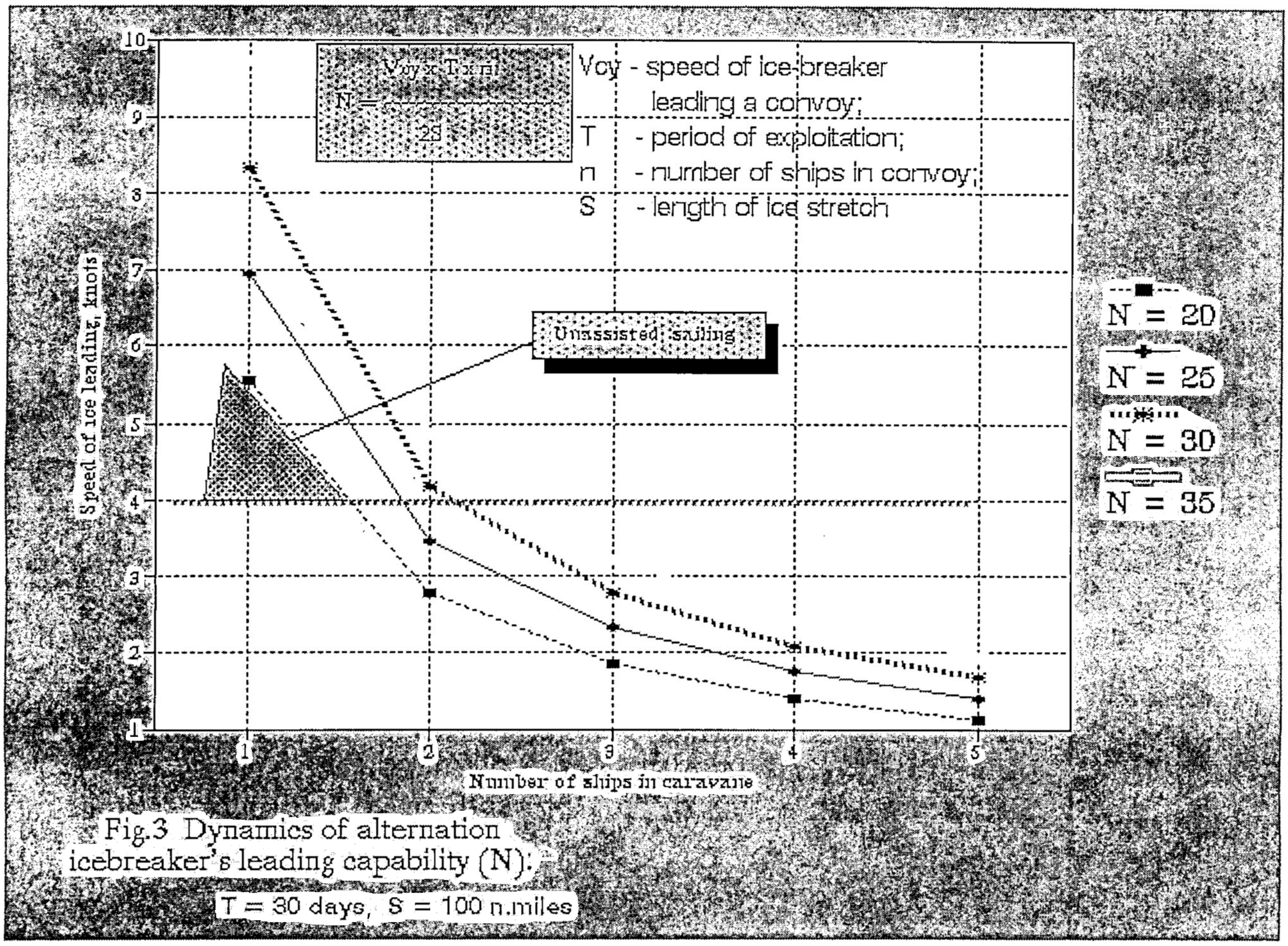

Fig.3 Dynamics of alternation icebreaker's leading capability (N):
T = 30 days, S = 100 n.miles

The above length of an ice-covered stretch of 100 miles long is typical of the period of heavy navigation in the areas of the Vilkitskiy and Long straits, as well as along the route Karskiye Vorota - Dudinka. The passages through heavy stretches (e.g. Long Strait) show that the speed of icebreaker leading decreases to 3-4 knots with unfavourable winds and ice compression; so the convoy is unable to make way. The vessels involved have to drift in ice and wait for better navigational situation (see Section 4.4). Owing to the above, the calculations in regard to positioning of icebreakers along the stretches with heavy ice conditions are based on a minimum admissible speed of leading i.e. 4 knots.

All the following sections 3-7 and Appendix 3 are based on both specific examples and a great body of measurements for the basic types of Arctic ships. All these specific examples and results can be used to establish under-way tasks for particular ships.

The diagram (Fig. 3) shows that one icebreaker with two vessels in convoy can lead 30 vessels during the above period of operation. Optimum results are achieved when icebreakers are positioned with due regard to their increasing leading power. Computerized calculations made in accordance with the suggested algorithm fully correspond to the actual results of the fleet operations. The same diagram shows that, if speed is reduced to 4 knots and less while the vessel is in an individual unassisted sailing in ice, the use of icebreakers will become commercially reasonable.

2. MODEL OF FORMING NAVIGATIONAL SCENARIOS FOR SAILING ALONG THE NSR

The aim of the paper is to work out scenarios of navigation along the NSR and to prepare operational recommendations to icebreakers and transport vessels. The recommendations are to be based on methods of simulation of weather and ice conditions. A navigation scenario suggests simulation of navigational conditions met in the course of sailing and optimal routes to ensure performance of safe voyage within the shortest period. A model forming scenarios of seasonal and year-round sailing along the NSR is shown on Fig. 4. Any model is based on expert-analytical assessment of scenarios in which various forecasts and the latest warnings on changes in navigational situation are taken into account.

With regard to times of reception and types of information the data may be grouped as follows:

- prognostic,
- current,
- specific,
- tactical reconnaissance effected by helicopters carried on board icebreakers.

Prognostic information includes:

- daily forecasts of hydrometeorological situation,
- surface analysis of hydrometeorological situation,
- hydrometeorological forecast for two days,
- ice situation forecast for three days.

Current information for the forthcoming day includes:

- weather charts (every three hours),
- ice information for 1 day,
- complex ice chart showing distribution of ice, its characteristics, direction of navigable routes.

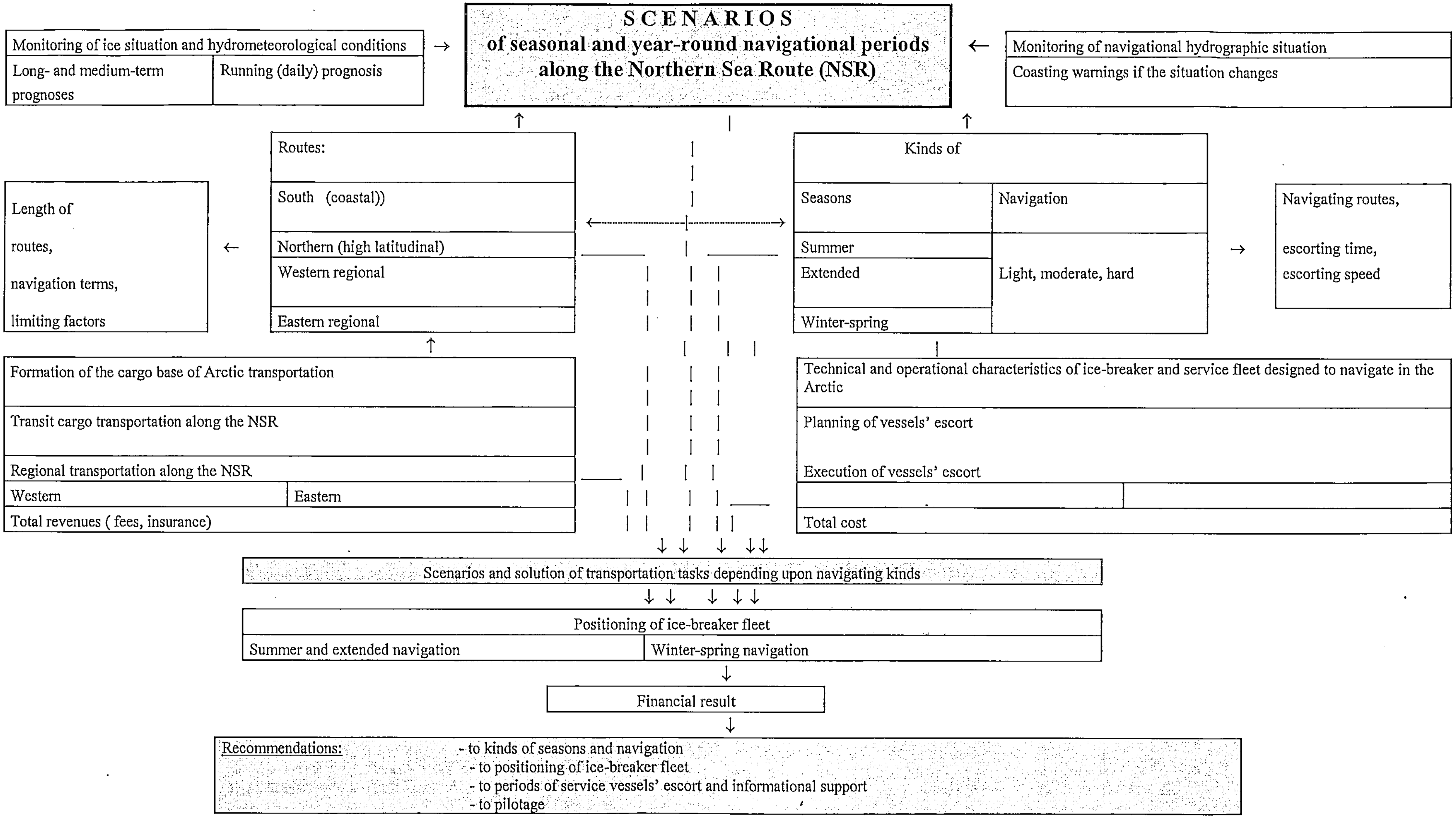

Fig. 4. Model of forming scenarios of seasonal and year-round navigation along the NSR

Vessels are supplied with specific information by the Marine Operations Headquarters or the Arctic and Antarctic Scientific Research Institute on request. All types of information are transmitted on board vessels in textual and charted variants. The received information will fully suffice to choose the most advantageous route and optimal speed.

Depending on periods of sailing there exist the following types of navigation:

- summer (July-September);
- prolonged (October-November),
- winter-spring (December-May).

Depending on ice conditions along the routes in a particular region, navigation may be divided into 3 types:

- light navigation,
- medium navigation,
- heavy navigation.

In accordance with the established practices of leading vessels in ice, the types of navigation are determined separately depending on seasons of navigation in the Western and Eastern regions of the NSR. Scenarios of navigation along the typical routes (Fig.5) are worked out by the systems approach to the problem. The approach makes use of the results of long-term research into natural conditions in the Arctic seas and of the experience in organization of regional and transit transportation of cargoes along the NSR.

2.1. Factors and Criteria for the Assessment of Scenarios

The following kinds of transport operations have been considered in the paper:

- regional transport operations in the Western Arctic area;
- regional transport operations in the Eastern Arctic area;
- transit transportation along the NSR.

The work of a vessel is assessed by the time spent to carry out certain operations such as loading, passage and discharge, to perform compulsory port formalities and to execute cargo documents.

The total time required for a voyage of a transport vessel (ΣT) may be found by summing up the following time intervals:

$$T = T_l + T_{st} + T_d = T_p + T_{st} \text{ (in days)},$$

where: T_l - the loading time,

T_{st} - the steaming time,

T_d - the disembarking time.

T_l and T_d are port components of the voyage T_p. Particular operations of the voyage are considered from the point of view of two main time intervals spent in port and under way. When the vessel is in berth her work is assessed by the time norms and quotas specified for particular operations depending on the customs of the port or requirements to safe operation of the vessel and safe transportation of cargo. When the vessel is under way, her work is assessed by the time spent on making the designated voyage (either loaded or in ballast) as well as on overcoming difficulties of navigational conditions, which may result in decreasing vessel speed as compared with technical (trial) one.

The main reason for changes in the steaming time of the voyage T_{st} is changes in vessel speed. The changes greatly depend on periods of navigation and conditions of sailing: unassisted voyage or icebreaker leading (in convoy or in tow, i.e. in tandem).

$$T_{st} = \Delta T_1 + \Delta T_2 + \Delta T_n$$

There are a number of factors, which in the course of sailing along the route cause reductions of vessel speed and, consequently, an increase in ΔT_{st}. These factors are:

- manoeuvring regime when leaving ports,
- reductions of speed when embarking and disembarking pilots,
- sailing through narrows and other shoal waters,
- taking the vessel in tow when following the icebreaker,
- breaking the ice around the vessel sealed in ice,
- unassisted sailing in ice conditions,
- following the icebreaker in convoy in ice conditions.

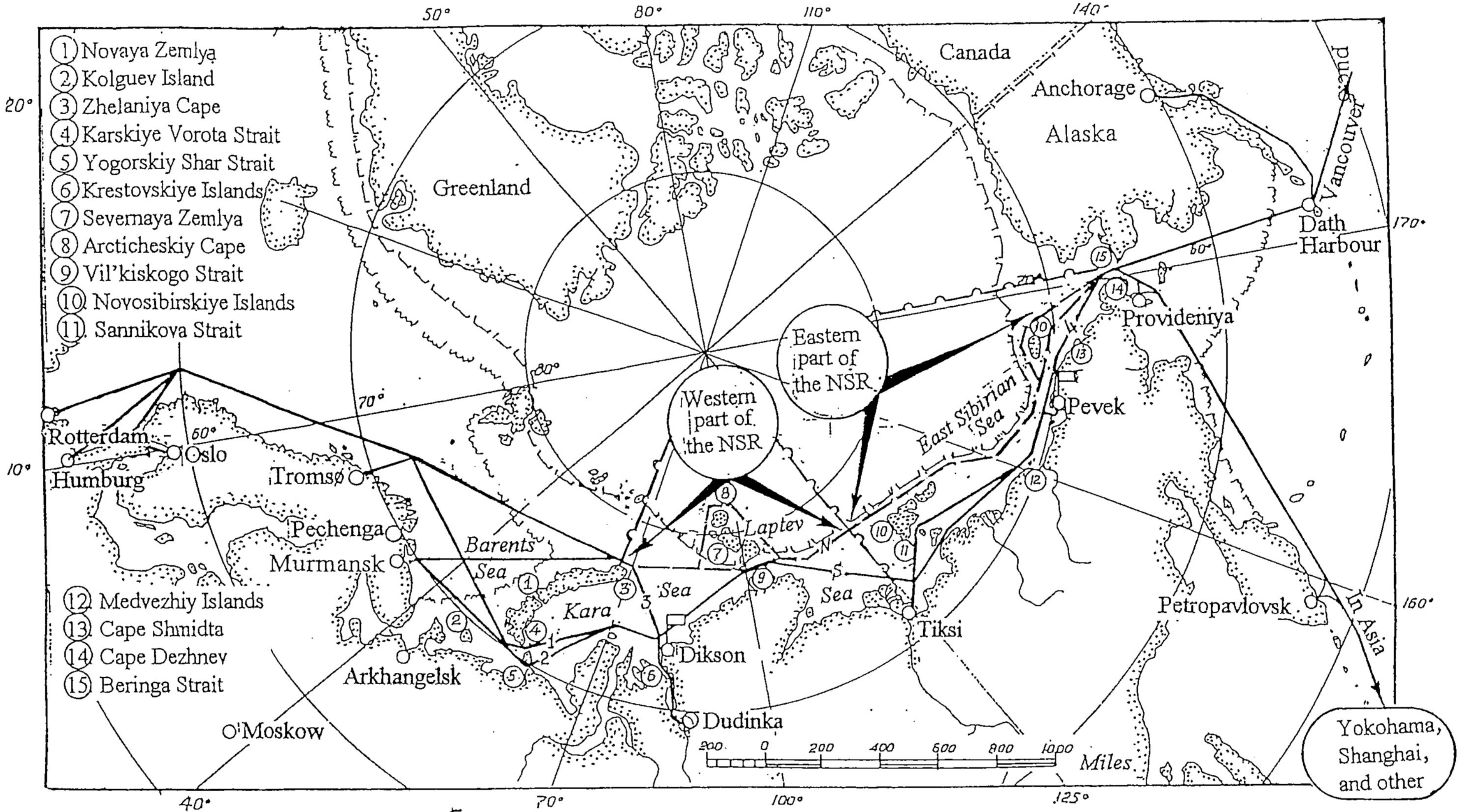

Fig. 5. Variants of routes of the Northern Sea Route (NSR)

- S - Southern (coastal) transit route - 2680 nm
- N - Northern (high latitude) transit route - 2446 nm
- 1 - Regional route
- Borders of the NSR
- Average of ice border in period of maximum of spreading
- Average of ice border in period of minimum of spreading
- Marine Operations Headquarters (Dikson and Pevek)

The main criterion of changes in the steaming component of the voyage T_{st} may be noticeable changes in vessel speed which vary considerably depending on periods of navigation, hydrometeorological and ice conditions along the route, unassisted sailing or icebreaker leading.

A special system of coefficients registers and corrects all changes in vessel's (convoy's) speeds for each particular scenario. The following are the factors causing changes in vessel speed and time under way, coefficients and calculation formulas to assess their values:

I When in clear water, the trial speed may be reduced to cruising one owing to changes in the vessel's age and is measured by the coefficient of cruising speed

$$C_c = V_c / V_t \quad (C_c = 0.95\text{-}0.90),$$

where: V_c - cruising speed in knots;

V_t - technical (trial) speed in knots;

2. The cruising speed may be reduced during unassisted sailing in ice, these reductions of speed will vary widely depending on ice conditions and are measured by the coefficient of speed in ice

$$C_i = V_i / V_c \quad (C_i = 0.85\text{-}0.40);$$

3. Reductions of cruising speed when sailing in ice following the icebreaker, either in convoy or in tandem, are measured by the coefficient of sailing in convoy

$$C_{cy} = V_{cy} / V_c, \quad (C_{cy} = 0.80\text{-}0.70),$$

where: V_{cy} - is the speed of leading the convoy (vessel);

4. Changes in the length of path related to a certain stretch (segment) when sailing through broken ice by altering courses are measured by the coefficient of manoeuvring.

$$C_m = S_i / S_n \quad (C_m = 1.05\text{-}1.35),$$

where: S_i - is the length of a stretch in ice, in miles,

S_n - is the navigable length of this stretch in clear water, in miles.

Navigators take decisions to correct speed and alter course, when sailing through openings in ice, according to visual observations and operational aircraft reconnaissance information.
Dr. Smirnov V. P. (the master of the nuclear barge-carrier "Sevmorput") suggested a method to estimate speeds in ice conditions by means of a system of coefficients. The method can be used for main types of Arctic-going vessels and is based on long-term experience in sailing along the NSR and in other regions of the Russian Arctic.

3. SCENARIO OF NAVIGATION IN THE WESTERN REGION OF THE NSR (MURMANSK - DUDINKA)

Professionals consider the following export-import cargo-flows as very promising in the Western Arctic region:

- export of products from the Norilsk mining-metallurgical works through the port of Dudinka; timber goods from the regions adjoining the river Yenisey - through the port of Igarka; coal from the Taimyr peninsula - through the port of Dikson (in the future);
- export of crude oil, oil products and gas from the shelf and coasts of the Barents and Kara seas;
- delivery of supplies and equipment to develop ore, oil and gas deposits, and of victuals for local population of those regions as well.

During the last 15 years traffic to the port of Dudinka continued all the year round by means of multipurpose transport vessels: bulk-carrying vessels and other types of specialized vessels. Atomic and diesel icebreakers effect leading in autumn and winter navigational periods (Appendix 1).

Winter sailing is effected along the following stretches:

- clear water (Barents sea),
- drifting ice (Barents and Kara seas),
- fast shore-ice in the river Yenisey.

In summer sailing is effected through ice only along the stretch from the Karskiye Vorota to the Krestovskiye islands.

3.1. Outline of Scenario and Solution of Transport Problem of the Murmansk - Dudinka Voyage with Regard to Periods of Navigation

An analysis of changes in speed characteristics and choice of correction factors will be made for seasons and types of navigation. Route 1 (Fig. 5) will serve as a basic route.

The length of particular stretches along the route differing in sailing conditions will be:

- Murmansk - Kolguev Island - 360 nm - 25%

- Kolguev Island - Karskiye Vorota - 210 nm - 15%
- Karskiye Vorota - Krestovskiye Islands - 570 nm - 42%
- Krestovskiye Islands - Dudinka - 260 nm - 18%

Speeds of icebreakers effecting leading of vessels along the route with regard to periods of navigation and ice conditions on separate stretches of the route for autonomous sailing have been chosen as follows (Table 1):

Table 1

Speeds of icebreakers (atomic icebreakers "Arktika" and "Taimyr") leading vessels in particular months (knots)

Type of navigation	August	October	December	February	April
Light	17.2	16.5	13.2	11.0	10.2
Medium	15.5	14.2	12.0	10.2	7.5
Heavy	13.1	12.7	9.2	6.9	5.8

The statistical data have proved that the speeds of convoys on certain stretches may differ significantly from those indicated in the Table, especially in heavy ice conditions of spring and winter periods.

3.2. Summer Navigation (July - September)

In the period of summer navigation the character of ice conditions along the routes depends upon the cyclones activity in the preceding winter period. This activity, in its turn, influences the drift of ice northward and location and limits of the Novaya Zemlya ice-massif, which determine the character of navigation with regard to the difficulties and ice conditions on separate stretches of the route.

In the period of summer navigation, ice conditions of various grades of heaviness are typical of the stretch from Novaya Zemlya Straits to Dikson Island. In the months from July to September sailing of vessels along this route is mostly effected without icebreaker assistance. The latter becomes inevitable along a few stretches only to overcome ice-bridges composed of remaining ice. Speeds of vessels are approximately the cruising ones.

Table 2 shows average estimated speeds and times required for the vessels of the Murmansk Shipping Co. (MSC) to sail from Novaya Zemlya Straits to Dikson Island depending on types of summer navigation.

Table 2

Average estimated speeds and times required for the vessels of the MSC to sail from the Novaya Zemlya Straits to Dikson Island depending on types of summer navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (time of sailing in ice)	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (10%)	16.5	3.5	14.0	3.5	13.5	4.4	13.0	4.5
Medium (20%)	15.0	4.0	13.5	4.4	12.5	4.7	12.3	4.7
Heavy (30%)	13.5	4.4	12.35	4.7	11.7	5.0	11.7	5.0

Coefficients of cruising speed reduction, when sailing in ice, C_i depend on types of navigation and are characterized by the following figures:

- light navigation - $C_i = 0.90\text{-}0.85$,
- medium navigation - $C_i = 0.85\text{-}0.80$,
- heavy navigation - $C_i = 0.80\text{-}0.75$.

Registration and corrections of the T_{st} estimated values along the route should be made every watch proceeding from ice conditions of sailing, daily and 6 hour forecasts and the data received by means of tactical ice reconnaissance.

3.3. Prolonged Navigation (October - November)

Active ice formation along routes 1, 2, 3 (Fig. 5) commences in this period. The process begins over fresh-water shoal patches of the Yenisey river. By the end of October the limit of ice formation in the whole area of remaining ice in the Kara Sea lies along the line of Bely Island - Pakhtusova Island. By the middle of November ice reaches the coast of Amderma. The thickness of freshly frozen ice is 20-25 cm, later fast shore-ice starts forming.

Sailing in clear water is effected along the stretch from Murmansk to the Karskiye Vorota Straits. Sailing of transport vessels along the other stretches of the route requires icebreaker leading, the icebreakers being stationed in places where accumulation of ice masses remains.

Table 3 shows the average estimated speeds and times required for the vessels of the MSC to sail from Novaya Zemlya Straits to Dikson Island depending on possible types of prolonged navigation when sailing in convoys.

Table 3

Average estimated speeds and times required for the vessels of the MSC to sail from Novaya Zemlya Straits to Dikson Island depending on possible types of prolonged navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (time of sailing in ice)	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (40 %)	14.2	4.1	12.7	4.6	11.7	5.0	11.7	5.0
Medium(55 %)	12.4	4.7	11.7	5.0	10.4	5.6	10.4	5.6
Heavy (70 %)	12.1	4.8	9.7	6.0	9.7	6.0	8.3	7.0

Coefficients of cruising speed reductions, when sailing in ice C_i ,depend on types of navigation. The coefficients are characterized by the following figures:

- light navigation - $C_i = 0.83\text{-}0.78$,
- medium navigation - $C_i = 0.78\text{-}0.68$,
- heavy navigation - $C_i = 0.67\text{-}0.63$.

Registration, and correction of the steaming time along the route are made every watch. Whenever necessary (during drastic changes in ice conditions or because of results of ice reconnaissance) the registration and correction of speed are made every hour.

3.4. Winter-Spring Navigation (December - May)

By the commencement of navigation, the formation of fast shore-ice is observed in the sea narrows along the whole length of the route. Intensive thickening of ice occurs in the river and gulf of Yenisey as well as in the Novaya Zemlya ice-massif.

In the Kara and Barents Seas, the thickness of fast shore-ice is 110 -140 cm, in the gulf and river Yenisey it is 170-200 cm. In drifting ice-massif it is 30-50 cm less. The formation of the

Novaya Zemlya ice-massif is completed in the Kara Sea in February, and in the Pechora and Kara Seas it is over in March.

Unassisted sailing is feasible only as far as Kolguev Island, and in the periods of heavy navigation as far as the meridian of Svyatoy Nos or Kanin Nos. The speeds of convoys in the process of icebreaker leading depend on the ability of vessels to follow the leading icebreaker along the canal.

Table 4 shows the average estimated speeds and times required for the vessels of the Murmansk Shipping Co. to sail from the Novaya Zemlya Straits to Dikson in convoys, depending on the types of winter-spring navigation.

Coefficients of cruising speed reductions, when sailing in ice C_i ,depend on types of navigation and are characterized by the following figures:

- light navigation - $C_i = 0.58$-0.54,
- medium navigation - $C_i = 0.53$-0.46,
- heavy navigation - $C_i = 0.46$-0.40.

Table 4 shows that the speed of the icebreaker leading a convoy along the route depends on the speed and engine capacity of the least powerful vessel in convoy.

Registration and correction of speed changes are made every watch and every hour depending on the actual situation of sailing and results of helicopter reconnaissance.

Table 4

Average estimated speeds and times required for the vessels of the MSC to sail from the Novaya Zemlya Straits to Dikson in convoys, depending on the types of winter-spring navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (time of sailing in ice)	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (70 %)	9.7	6.0	9.0	6.5	8.3	7.0	8.3	7.0
Medium (80 %)	8.3	7.0	8.3	7.0	7.3	8.0	7.3	8.0
Heavy (90 %)	7.3	8.0	6.4	9.0	6.4	9.0	6.4	9.0

3.5. Estimation of Voyage Duration According to Types and Periods of Navigation

In estimating the duration of a voyage with due regard to ice conditions and periods of navigation, the coefficients of route lengthening C_m and that of cruising speed reduction, when sailing in ice C_i, should be taken into account:

$$T_{st} = S_i / V_{cy},$$

where: $S_i = S_n * C_m,$

$V_{cy} = V_c * C_i * C_{cy}.$

Conclusions:

Simple calculations result in the following figures showing an increase in voyage duration depending on the periods of navigation:

- In summer period an increase in T_{st} does not exceed 10-15%, i.e. transport vessels proceed along the route at a speed which is practically very close to the cruising one. Thus, it becomes possible to organize functioning of vessels according to liner schedule/container-carrier lines - Arkhangelsk - Dudinka - Arkhangelsk, rhythmic import of ore and various products on Murmansk –Dudinka -Murmansk line.
- Practical experience of the MSC vessels proved that the icebreaker leading along the routes makes it possible to operate merchant fleet on these lines.
- A 50% to 70% increase in the steaming component of the voyage T_{st} will require an

additional number of vessels only during periods of heavy navigation.

- Loss of the steaming time when sailing along these routes in winter-spring period may be quite significant. Duration of passage through ice-covered stretches of the route may increase by 120-150%, which will require an additional number of vessels to transport existing volumes of cargoes. Besides, voyage expenses increase substantially owing to: 100% use of icebreaker leading along the routes, mooring operations in ports and clearing of loading berths from ice before mooring.

4. SCENARIO OF NAVIGATION IN THE EASTERN REGION OF THE NSR (VLADIVOSTOK - PEVEK)

The following kinds of cargo form the cargo-flows, which require transport vessels to operate on this line:

- transportation of mineral fertilizers and timber products from the Eastern regions of Russia;
- transportation of ores, products of mining-metallurgical works and scrap from the region;
- transportation of coal from the Zyriyansk and Bering deposits;
- delivery of fuel, equipment and victuals to develop the economy of the region and supply local population.

Seasonal character is a typical feature of merchant fleet operations in the eastern region of the Arctic. Navigational period for transport vessels, as a rule, continues along the regional routes from July to October, i.e. approximately one month shorter than that in the western sector of the Arctic. It mostly depends on heavy ice conditions.

The ice situation in the region and along the route is influenced by thermal conditions over North Chukotka in spring and dynamics of ice processes, which determine the location of the Ayon and Vrangel ice-massifs and the Koljuchinsk ice patch. Warm or normal thermal conditions cause intensive thawing of ice, development of the Chukot open glade along the Chukot coast and an easy ice situation in the Chukchi Sea. While there are cold thermal conditions in this region, the above processes do not take place, and so a significant percentage of pack ice remains in ice-massifs.

Unfavorable dynamic processes in the air, which are caused by cyclones, result in drifting ice fields to the south. These ice fields obstruct the Long Strait with heavy ice; pressure ice fields and forming of hummock ice is also observed in this situation, which make unassisted sailing of vessels along the routes impossible. Icebreaker leading becomes extremely difficult even for atomic icebreakers.

Therefore, when working out the scenario, the navigation are treated according to the severity of sailing conditions:

- light navigation,
- medium navigation,
- heavy navigation.

4.1. Outline of Scenario and Solution of Transport Problem of the Vladivostok - Pevek Voyage with Regard to Types of Navigation

The steaming time T_{st} may change (when vessels are passing through separate stretches which differ both in the character of ice and hydrometeorological situation) due to changes in speed and alteration of vessel's courses in order to round ice fields, which increase the length of the route.

An analysis of speed changes and the choice of correction factors for different ice conditions have been made with regard to types of navigation.

The length of certain stretches of the route differing in ice navigation conditions and times to cover them are as follows:

- Vladivostok - Cape Dezhnev - 2550 nm,
- Cape Dezhnev - Koljuchin Island - 150 nm,
- Koljuchin Island - Cape Shmidta - 140 nm,
- Cape Shmidta - Cape Shelagskiy - 160 nm,
- Cape Shelagskiy - Pevek - 40 nm.

When calculating coefficients, changes in the steaming time T_{st} will be considered only for the stretches from Cape Dezhnev to Pevek. Difficult ice conditions, which considerably increase the duration of voyage, are typical of these stretches.

4.2. Light Navigation

During light, with regard to ice conditions, navigation the eastern limit of ice lies approximately westward of Cape Dezhnev along the meridian of Cape Serdze Kamen. The Koljuchin ice patch is subject to substantial destruction; the Ayon and Vrangel ice-massifs do not obstruct the Long Strait.

Long-term observations prove that remaining ice may be met along Koljuchin Island - Cape

Shmidta - Cape Shelagskiy – the port of Pevek in the periods of light navigation as follows:

- opening and final periods of navigation - 20-25%,
- middle period of navigation - 10-15%.

There is a strong probability, that ice-coverage along the above stretches may extend owing to formation and growth of fresh ice in the freezing period which commences from the last third of September till mid-October, depending on the year.

The tactics of icebreaker leading in the eastern region of the NSR differ from those in the western region of the Arctic. Direct passage through the ice of the Ayon and Vrangel ice-massifs is difficult. The courses of convoys are shaped through patch of ice-free water to round ice-massifs, thus causing lengthening of the route and reductions of speed, i.e. an increase in the steaming component of the voyage:

$$S_i = S_n * C_m$$

where: S_n - navigational length of a stretch in clear water in miles;

C_m - manoeuvring coefficient.

The values of coefficients reducing speeds for various ice conditions along separate stretches of the route and actual speeds are shown with regard to periods of navigation (Table 5).

The coefficient of speed reduction when sailing through ice-covered stretches of the route is:

$$C_i = 0.83 - 0.73$$

Table 5

Average estimated speeds and times of passage required for the vessels of the MSC to sail along the route: Koljuchin Island - Cape Shmidta – Cape Shelagskiy - Pevek in the period of light navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (C_m / time of sailing in ice)	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (1.15-1.32 / 25%)	12.5	1.4	11.2	1.6	10.7	1.8	10.0	1.8
Light (1.10-1.20 / 15%)	13.1	1.2	12.3	1.4	11.5	1.6	11.5	1.6

Unassisted sailing of the above vessels is feasible in the periods of light navigation, depending on ice conditions. Icebreaker leading becomes necessary only in the final period of navigation to pass through certain patches of close pack.

4.3 Medium Navigation

Medium navigation conditions are observed along the above route when there is remaining ice in the Koljuchin ice patch; at the same time, the routes running along the southern parts of the Ayon and Vrangel ice-massifs are shifted to the latitude of the Long Strait.

The limit of ice-covered stretch of the route in the East will be found approximately 80-100 miles westward of Cape Dezhnev. The length of ice-covered stretches along the route is from 20 to 40% depending on periods of navigation (commencement - middle - end) and initial periods of freezing in corresponding years.

Speeds of vessels and relevant correction factors for medium ice navigation are shown in Table 6.

The coefficients of cruising speed reduction when sailing in ice C_i are as follows:

$$C_i = 0.75 - 0.62.$$

Table 6

Average estimated speeds and times of passage required for the vessels of the MSC to sail along the route: Koljuchin Island - Cape Shmidta – Cape Shelagskiy - Pevek in the period of medium navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (C_m / time of sailing in ice)	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Medium (1.17-1.35 / 40 %)	10.7	1.5	9.3	186	7.9	2.0	7.9	2.0
Medium (1.10-1.22 / 20 %)	12.2	1.3	11.5	1.5	9.7	1.8	9.7	1.8

Unassisted sailing along the route is feasible in the middle of navigation; icebreaker leading is required during the rest of the period. Sailing along the route carried out by the atomic barge-carrier "Sevmorput" is an exception as this vessel has extra strengthening, high power reserve and speed manoeuvrability.

4.4. Heavy Navigation

Heavy, with regard to ice conditions, navigation (observed once or twice a decade) is a result of cold isothermal conditions over the north of Chukotka. The Koljuchin ice patch extends eastward; the Ayon and Vrangel ice massifs occupy areas southward of the usual ones, these phenomena result in accumulation of large ice masses in the Chukchi and East Siberian Seas. There is a strong probability that the Long Strait is obstructed with ice. Heavy pack ice along certain stretches of the route makes navigation difficult along the whole length of the route.

Ice patches of various degrees of compactness may be met already about Cape Dezhnev. At the beginning and end of abnormally heavy navigation, the ice patches extend as far as 200-360 miles southward of Cape Dezhnev.

The speeds and correction factors for the above vessels on the selected routes are shown in Table 7.

Table 7

Average estimated speeds and times of passage required for the vessels of the MSC to sail along the route: Koljuchin Island - Cape Shmidta - Cape Shelagskiy - Pevek in the period of heavy navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (C_{ii} / time of sailing in ice)	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, Days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Heavy (1.10-1.25 / 55 %)	8.4	1.9	7.0	2.3	5.8	2.7	5.8	2.7
Heavy (1.05-1.17 / 30 %)	9.9	1.5	8.2	1.7	7.3	2.0	7.3	2.0

The coefficients of cruising speed reduction when sailing in ice are as follows:

$$C_i = 0.55\text{-}0.45$$

In the periods of abnormally heavy navigation speeds of icebreaker leading, especially along the stretch of Long Strait, are reduced to V_{cy} = 3.0-4.0 knots. When these conditions are accompanied by unfavorable winds or by ice compression, sailing of convoys becomes practically unfeasible, and the vessels have to drift with ice and wait for better navigational situation.

Corrections of speed are made every watch with hourly amendments depending on the results of helicopter reconnaissance.

Sailing along this stretch is feasible only with icebreaker leading.

4.5. Estimation of Voyage Duration with Regard to Types and Periods of Navigation

The estimation of voyage duration when passing through an ice-covered stretch of the route should take into account lengthening of the route which is to be determined by coefficient C_m, and correction of speed by coefficient C_i:

$$T_{st} = S_I / V_{cy},$$

where: $S_i = S_n * C_m,$

$V_{cy} = V_c * C_i * C_{cy}.$

The calculations show that losses of steaming time (ΔT_{st}) depending on types of navigation are:

- light navigation - 10-15%,
- medium navigation - 20-35%,
- heavy navigation - 35-70%.

Conclusions:

- Thus, in the periods of light navigation vessels proceed to the port of Pevek practically at cruising speed which needs to be reduced to manoeuvring speed when passing through ice-covered stretches, i.e. unassisted sailing.
- In the periods of medium navigation, icebreaker leading is used for passing through ice-covered stretches, especially at the beginning and end of navigational period.
- In the periods of heavy navigation, icebreaker leading is used for sailing along the whole route.

5. SCENARIO OF TRANSIT NAVIGATION DEVELOPMENT

Long-term practical experience in organization of cargo transportation along the NSR by the Russian shipping companies from the East (Far-Eastern Shipping Co.; Primorskoye Shipping Co.; Sakchalinskoye Shipping Co.) and from the West (Murmansk Shipping Co.; Northern Shipping Co.), with transit voyages included, proves that the NSR is a stable and reliable seaway in the Russian North.

Opening of the NSR for foreign shipping companies, their commercial interest in effective sailing in the above region may give rise, in the near future, to large scale international cargo flows from Western Europe, Scandinavia, Japan, North America and Canada.

The following cargo-flows may be suggested as promising ones:

- bulk cargoes: ores, coal, metals to Japan and China;
- container transportation in both directions;
- fertilizers from Kola peninsula to China;
- export of oil and oil products from the Russian Arctic.

According to the UNO data, up to 7-8 million tons of transit cargoes may be switched over to the NSR.

While considering organization of transit transportation, it should be taken into account that transit voyages along the NSR must meet the following criteria:

1. Regularity and reliability of transit transportation.
2. Safety of vessels and cargoes in the course of transportation along the NSR.
3. Saving of time as compared with West - East voyages and return voyages made by southern routes.

Judging by the experience achieved in operation of the Russian merchant fleet (its active transport vessels and icebreakers), the organization of seasonal transit voyages is feasible only during summer and prolonged periods of navigation in the Arctic.

Two routes of transit transportation have been selected for individual vessels and convoys in

the WP1 project (Fig.5):
- coastal (Southern Arctic),
- high-latitudinal (Northern Arctic).

The selection of route for a particular voyage depends on long-term and current forecasts of ice and hydrometeorological situation existing at the time of commencement of a voyage, and on the vessel's draft.

5.1. Outline of Scenario of Transit Navigation and Solution of Vessels' Transport Problem (Murmansk - Vladivostok)

When solving the transport problem, the coastal (Southern Arctic) route of the NSR has been taken as the main one.

The following are the stretches of the selected transit route:

- Murmansk - Karskiye Vorota Strait - 570 nm,
- Karskiye Vorota Straits - Dikson Island - 492 nm,
- Dikson Island - Vilkitskiy Strait (Cape Cheliyskin) - 367 nm,
- Cape Cheliyskin - Medvezhiy Islands - 546 nm,
- Medvezhiy Islands - Cape Shelagskiy - 660 nm,
- Cape Shelagskiy - Koljuchin Island - 315 nm,
- Koljuchin Island - Cape Dezhnev - 150 nm,
- Cape Dezhnev - Vladivostok - 2550 nm.

Location and development of the Novaya Zemlya, Severnaya Zemlya, Taimyr, Ayon and Vrangel ice-massifs influence greatly the ice situation and type of navigation along the NSR. The development of the ice-massifs in winter period, thawing, destruction of ice fields, drift in spring and early summer – all these circumstances determine the character of ice situation in the Arctic seas and difficulties in ice situation on a certain stretch of the route in dependence of the season of navigational periods.

Most difficult for sailing are the following stretches:

- Karskiye Vorota Strait - Dikson Island,
- Vilkitskiy Strait,

- Sannikov and Dmitry Laptev Straits,
- Long Strait.

In the western region of the Russian Arctic a substantial destruction and thawing of ice masses adjoining coastal shoal waters take place due to great outflow of warm waters from the rivers Ob, Yenisey and Lena in the spring-summer period. This phenomenon improves sailing conditions considerably and makes it possible to commence navigation along the route in earlier periods and proceed at higher speed both in unassisted individual voyages and in convoys.

In the eastern Arctic region, there is no such outflow; coastal stretches of the route are subject to ice obstruction during northerly on-shore winds. High percentage of pack in ice-massifs, high degree of hummock and strength of ice cause difficulties in ice sailing at the beginning and especially in the end of navigational periods.

In summer and prolonged periods of navigation, organization of transit passages along the NSR presents no difficulties.

An analysis of changes in speeds and determination of correction factors showing increases in duration of sailing along the route T_{st} will be made with due regard for types of navigation (with respect to ice conditions) and seasons of navigation.

5.2. Summer Navigation (July - September)

The said period is considered to be the most favorable for transit sailing along the route. The location of the Siberian anticyclone which determines thermal conditions over the central and eastern regions of the NSR influences ice conditions there and accelerates the process of thawing and clearing from ice of the coastal route.

The average length of the route is 2.530 nautical miles though it may change from 2.100 to 3.400 miles. Most probable route will lead from Murmansk through the Karskiye Vorota Strait to Dikson Island, through the Vilkitskiy Strait in the west, along the southern edge of the Taimyr ice-massif (or through it) to the Laptev Sea, through the Novosibirskiye Straits, then farther eastward along the Chukot coast to the Bering Straits. In the initial period of navigation, both in the East and in the West, sailing in difficult ice stretches is effected in the canals made by icebreakers or in convoys.

Speeds of sailing through ice-covered stretches are shown in Table 8.

Table 8

Average estimated speeds and times required for the vessels of the MSC to sail along the NSR according to types of summer navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (time of sailing in ice)	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (10-15%)	13.6	6.2	12.5	7.3	12.0	8.1	12.0	8.1
Medium(20-30%)	12.5	7.1	10.8	8.2	9.7	9.0	9.7	9.0
Heavy (30-55%)	10.9	8.7	8.5	10.3	7.3	11.8	7.3	11.8

The correction factors for speed reduction when sailing in ice are as follows:

- light navigation - $C_i = 0.88\text{-}0.75$,
- medium navigation - $C_i = 0.72\text{-}0.69$,
- heavy navigation - $C_i = 0.57\text{-}0.52$.

Corrections and registration of speeds influencing changes in T_{st} are made during each watch.

5.3. Prolonged Navigation (September-November)

Prolonged navigation is effected in the period of active ice freezing in the Arctic seas. The length of the daylight decreases, which, in its turn, makes sailing conditions along the route much worse.

Freezing on the route stretches begins from the second third of September (Vilkitskiy and

Sannikov Straits) and continues till the end of October. The growth of ice-coverage to 20-25 cm thick occurs after 20 October, then fast shore-ice begins to form in coastal parts of the Chukchi Sea, Sannikov and Dmitry Laptev Straits.

The ice situation becomes more complicated especially in the final period of navigation with unfavorable northerly winds. Sailing along the route is usually effected by icebreaker leading.

Stationing of icebreakers along difficult stretches of the route is carried out under the Marine Operations Headquarters (the port of Dikson in the West and the port of Pevek in the East) after consultations with the NSRA Administration (Moscow).

Speeds of vessels along the route are substantially reduced when passing through ice-covered stretches. Speeds of vessels considered in the paper are shown in Table 9.

Table 9

Average estimated speeds and times required for the vessels of the MSC to sail along the NSR according to types of summer navigation

Vessel's type	"Sevmorput"		"Norilsk"		"Mikhail Strekalovskiy"		"Dmitry Donskoy"	
Type of navigation (time of sailing in ice)	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days	V_v, knots	T_{st}, days
Light (25-40%)	11.2	7.1	10.1	8.8	9.5	9.1	9.5	9.2
Medium (40-60 %)	10.3	8.2	7.5	10.5	6.7	11.7	6.7	11.9
Heavy (55-70%)	7.9	10.8	6.6	12.8	5.5	15.2	5.5	15.4

The correction factors showing reduction of cruising speed in various conditions of ice sailing are as follows:

- light navigation - C_i = 0.75-0.65
- medium navigation - C_i = 0.57-0.52
- heavy navigation - C_i = 0.45-0.42

Corrections of speeds should be made each watch; if there are sharp alterations of course, they are to be made every hour.

5.4. Estimation of Voyage Duration Depending on Periods and Types of Navigation

Increase in steaming component of the voyage T_{st} during passage from Murmansk to the Bering Strait is determined with regard for the extension of the ship route and reduction in ship's speed when forcing the way in ice - covered areas.

$$T_{st} = S_i / V_{cy},$$

where: $S_i = S_n * C_m,$

$V_{cy} = V_c * C_i * C_{cy}.$

The calculations show that the loss of T_{st} is about 10-20% in light and medium navigation and 25-45% in heavy ice navigation.

Conclusions:

- In the periods of prolonged navigation even atomic icebreakers are not capable to cover some segments of the route, especially in the Eastern part of it, where ice compression is usually brought about by northern winds. Comparative calculations of transit voyages from West European ports to the East (Hamburg - Murmansk - the NSR - Yokohama) in the period of summer navigation show a substantial saving of time, up to 10 days, if compared with traditional routes through the Suez Canal.
- The expenses for using icebreakers to escort ships in ice are largely exceeded by the rates of tariffs for passing through the Panama or Suez Canals, cost of time wasted in waiting for passing through the above canals etc.

6. SCENARIO OF TRANSIT NAVIGATION ALONG HIGH-LATITUDINAL ROUTE

Prospects for putting into service a new generation of transport vessels and container-carriers designed to sail in the Arctic and drawing 12-14 meters open the way for sailing along the NSR outside the coastal routes with their limited depths.

In the summer-autumn period the route leading southward of the edge of pack ice masses formed in the Arctic seas in winter period, northward of the isobath of 14.5-15.0 m, will be the most probable and profitable one.

The route leads from Cape Zhelaniya to the Vilkitskiy Strait, northward of the Novosibirskiye Islands, and further through the Long Strait to the Bering Strait.

In winter, transit passage from the Atlantic to Pacific ocean and in the opposite direction is feasible along the route running through non-freezing polynias located outside the fast shore-ice areas. The route runs as follows: Cape Zhelaniya - Cape Arkticheskiy (Severnaya Zemlya), northward of the Novosibirskie Islands and the Long Strait (the route northward of Vrangel Island is also possible) and further on to the Bering Strait.

Actual individual passages performed by the atomic ice-breakers ("Lenin", "Arktika", "Sibir") through non-freezing polynias outside fast shore-ice zone to the North Pole, from Murmansk to Pevek showed the feasibility of transit sailing by this route. The experience gained during these voyages also proved that sailing conditions in the ice of the East Arctic seas in summer periods appeared to be more difficult than in the close-to-the Pole region. The above experimental voyages may serve as practical basis for realizing the idea of a year-round high-latitudinal route.

It should be born in mind, however, that the existing experience is insufficient to state that transport vessels may safely and reliably use high-latitudinal routes. Necessary basic information for practical use of the above routes may be received only through organization and carrying-out of voyages of loaded transport vessels with icebreaker leading.

The nuclear barge-carrier "Sevmorput", being 260.3m long, 32.2m broad and drawing 12.0m, can serve as a prototype of new transport vessels. The above barge-carrier is equipped with a nuclear-powered engine of sufficient power to sail in difficult ice conditions and perform a wide range of speed manoeuvres within a short period.

The speed characteristics and ice transiting performance of the nuclear barge-carrier "Sevmorput" have been obtained during the work performed by a group of ship designers and CNIIMF's specialists on board the barge-carrier in October-November 1989 and during the operation of the ship on the NSR seaways and in the Yenisey River from 1989 to 1993.

To clarify the changes of ship's draft in shallow water under ice conditions, a series of field observations was made by Captain Smirnov V during the period from 1985 to 1992. The applied methods were agreed with the Maritime Service of the Murmansk Shipping Company and CNIIMF's branch office in Murmansk.

Observations were made on shallow water stretches of the NSR seaways: Sannikov strait, Buor Haya Bay, Yenisey River (river bar, Turushinsky rift, Bolshoy Island). Data were processed and coefficients calculated with the use of mathematical statistics techniques, with the following works [6,7,8] being consulted.

Proceeding from the results given in Sections 3-6, the computer-oriented estimation (Appendix 3) of transport schemes for the considered ships (the nuclear barge-carrier "Sevmorput", multi-purpose dry cargo ship "Norilsk" and bulk/container ship "Dmitry Donskoy") on the chosen routes of shipping for two types of navigation (for light navigation - optimistic forecast and for heavy navigation - pessimistic forecast) has been carried out.

The transport schemes for every ship operation have been carried out basing on ship's work-estimate-table data on the route. The characterizing stretches of route have been selected according to the following particulars: extension of stretches, speed, speed changing coefficient, manoeuvring coefficient. Quantity indicators of the transport schemes are estimated in the table by distance, day speed, time of passing stretches, time of round voyage.

For every type of navigation (summer, prolonged and spring) the operating schedules of passing ice stretches of the route are made up basing on the estimate table data.

Thus, the transport schemes proposed give us an opportunity to determine possible loss of time caused by passing of ice stretches of the route in dependence of forecasted type of navigation.

The next section deal with the following issues: design types of ships given in the task according to project III.07.8; basic technical and operation requirements to be taken into account in designing ships; potential operational and economic performances of ships on chosen routes with possible scenarios of Arctic navigation.

7. SCENARIO OF SEASONAL AND YEAR-ROUND NAVIGATIONS ALONG THE NSR FOR THE PERSPECTIVE TYPES OF VESSELS

7.1. Estimated Types of Vessels to Be Operated along the NSR

In accordance with the assignment on the project III.07.8 the following types of vessels are recommended for an economic appraisal of the scenario of seasonal and year-round navigation:

- general cargo-carrying vessel of SA-15 type;
- Arctic container-carrier capable of transporting 3,000 TEU and drawing 12.5 m;
- Arctic bulk ship capable of transporting bulk cargoes in the quantities transported by the Panamax type bulk carrier.

The feasibility of sailing in ice depends on such factors as strength and operating capabilities of the vessel's hull, devices and mechanisms in low temperatures; fullness of hull lines; type of propulsion plant; energy-supply equipment etc. (or on ice class which meets the requirements of a certain classification society). It is reasonable to consider two types of the above feasibility:

- year-round operation of vessels in the Arctic waters, mostly without icebreaker assistance, with icebreaker leading being rendered only in heavy ice conditions;
- operation of vessels in the Arctic waters in summer-autumn periods only; the length of the latter (prolonged navigation) depends on the vessel's ice-class.

The above levels of vessel's fitness to operate in ice conditions are ensured by the categories of ice-strengthening ULA (ÓËÀ) and UL (ÓË) of the Russian Register of Shipping respectively. Main technical and operating characteristics of the estimated types of vessels are shown in Appendix 1.

An analysis of operation of the "Ventspils" and "Samotlor" types of tankers transporting oil-products in the Arctic, has proved that during medium and heavy ice navigation the tankers of UL class suffer considerable damage to their bilges and middle parts of hull (up to 70% of all damage).

The damage can be explained by the fact that the turning ability of a tanker is much lower than that of an icebreaker. So, when the icebreaker alters her course, the tanker is unable to repeat the manoeuver accurately and breaks the ice-edge of the canal, made by the icebreaker, with her sides, thus suffering damage.

One should therefore draw a conclusion that strength and manoeuvrability of the UL-class vessels operating in the Arctic do not fully correspond to technical and operating characteristics necessary for vessels working in the Arctic.

We are of opinion that new vessels designed for sailing in the Arctic should meet the requirements of the ULA-class of the Russian Register of Shipping (Appendix 4). Newly-constructed vessels should be equipped with a propulsion plant of a sufficient power to accelerate speed of manoeuvres within a short time. The propulsion plant should be equipped with a controllable pitch propeller with a nozzle and air bubbling gear, which will also improve the vessel's manoeuvrability, steering qualities and safe operation in difficult conditions of sailing in the Arctic.

The ten years experience of heavy Arctic sailing gained by the nuclear barge-carrier "Sevmorput" proved the effectiveness of the controllable pitch propeller with a nozzle.

7.2. An Analysis of the Safety of Ice Navigation in Shallow Waters

The prospects of hydrocarbon production on the shelf of the Barents and Kara seas require an analysis of safe operation of transport vessels in shallow waters.

An analysis of the causes of various accidents occurred on the routes with limited depths has revealed both the errors in vessel's steering and insufficiency of information in the existing recommendations regarding safety of ice sailing in shallow waters.

Most important problems to be solved when sailing in ice in shallow waters are:

- possibility of taking coastal routes by vessels with permissible drafts (depending on shallow-water depths);
- determining of operational and objective water-ice-draft change when passing from open water into ice area and vice versa; selection of optimum speed when sailing in ice in

shallow waters;

- determining of depths safe for nuclear icebreakers leading vessels and convoys in shallow waters.

Direct observations conducted by Dr. Smirnov on the vessels of the Murmansk Shipping Co. (m/v "V. Korobko", m/v "Kapitan Bochek", atomic barge-carrier "Sevmorput") in accordance with the methods evolved showed that absolute figures of draft change are considerably different when sailing at equal speeds in open water and in ice.

Direct observations conducted during vessels' sailing in compact ice in shallow waters have proved the fact that the water flow along the ship's hull (G. Sukhomel's theory) in these conditions is of different character as compared with that experienced by the vessels sailing in clear water.

It has been noticed that the stern wave becomes lower, less steep and smooth even when ice is 40-50 cm thick. Consequently, the water-ice-draft change becomes smaller thus increasing the level of safety when sailing in shallow waters.

Processing of these observations by means of mathematical statistics gives the values of the correction factor C_i for sailing in shallow waters under ice conditions (in comparison with the water-ice-draft change in open water).

The estimated figures of the water-ice-draft changes in ice ΔT_S can be calculated using the following expression with the ice correction factor C_i:

$$\Delta T_S = \alpha_h * C_1 * \theta_\psi * C_i * V^2 \qquad (1)$$

Where: ΔT_S - the water-ice-draft change by stern, cm,

V - ship's speed, m/sec,

H - the depth along the ship's course, m,

T - ship's draft, m,

T/H - draft to depth ratio,

α_h - change of depth proportionality ratio,

C_l - ship's length correction factor,

θ_ψ - initial trim proportionality factor,

C_i - ice conditions correction factor.

The figures of coefficients and factors α_h, C_l, θ_ψ, C_i should be chosen from Tables 10, 11 and 12.

Table 10

Values of depth change proportionality factor α_h

T/H	0.35	0.40	0.45	0.50	0.55	0.60	0.65
α_h	0.0146	0.0155	0.0164	0.0174	0.0187	0.0201	0.0216
T/H	0.70	0.725	0.750	0.775	0.800	0.825	0.850
α_h	0.0232	0.0243	0.0250	0.0262	0.0274	0.0288	0.0300

Table 11

Values of ship's length C_i and initial trim proportionality factor to the ship's length L and initial trim Ψ_h

<table>
<tr><td>Ship's length L in m</td><td>Under 100</td><td>100-150</td><td>150-200</td><td>200-250</td><td>250-300</td></tr>
<tr><td>C_l factor</td><td>0.95</td><td>1.05</td><td>1.25</td><td>1.42</td><td>1.60</td></tr>
<tr><td>Initial trim</td><td>$\Psi_h = 0$</td><td colspan="2">$\Psi_h = 0.01$</td><td colspan="2">$\Psi_h = 0.02$</td></tr>
<tr><td>θ_Ψ factor</td><td>1.000</td><td colspan="2">1.025</td><td colspan="2">1.050</td></tr>
</table>

Table 12

Values of ice conditions correction factor C_i

Ice thickness, cm	30-40	40-50	60-80	90-100
Compactness	5-6	6-7	7-8	9-10
C_i factor	0.95	0.90	0.85	0.80

If the ship's stern water-ice-draft change is calculated by means of the formula (1), the data received are in full accordance with the results of direct observations.

The direct observations conducted on board the nuclear barge-carrier "Sevmorput" to determine the water-ice-draft change in ice conditions, ensured safe operations of the above vessel on shallow-water stretches of the NSR (Buor-Khaya Bay, Sannikov Strait, in the approaches to the port of Tiksi, in the Yenisey river etc.).

Application of observations enabled the navigators to pass the shallow-water stretches at optimum speeds and carry out cargo-handling operations in the port of Tiksi over minimum permissible depths, which was very important for the safe operation of an atomic icebreaker.

Calculations to determine the values of the water-ice-draft change for various shallow depth and ice conditions, can be made by means of expression (1). At the same time, a graph can be built (Fig. 6) for prompt determination of both the values of the water-ice-draft change ΔT_S and the corresponding ship's speed V.

Availability of the above information on the vessel's bridge enables navigators to act more confidently when sailing in shallow waters. The information regarding the water-ice-draft change (Tables 10, 11, 12 and the graph) should be entered in the ice-passports of newly-built transport vessels and tankers sailing in ice conditions.

Puc.6

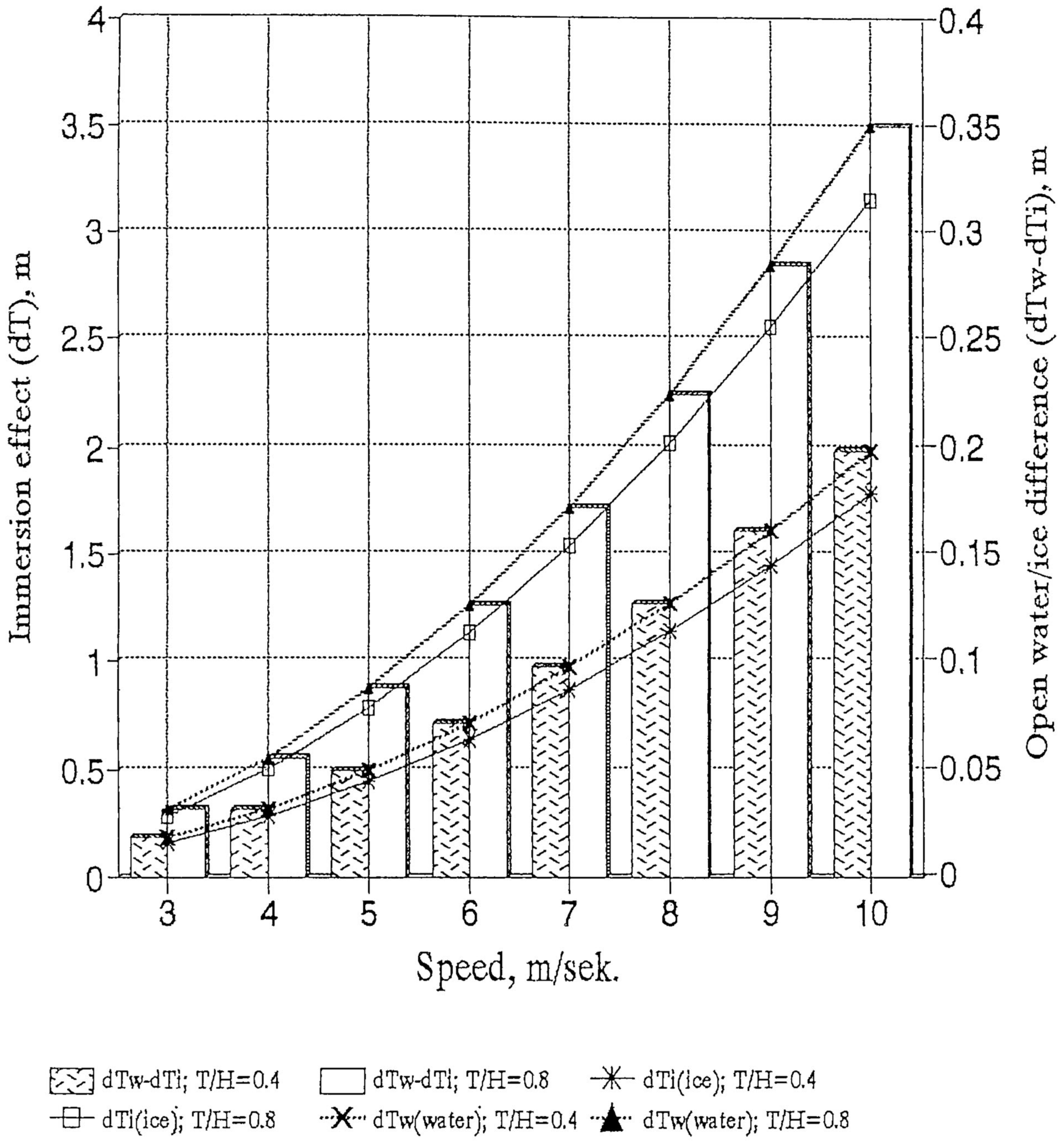

Fig.6 Analysis of safe sailing in ice & shallow water.

7.3. Effectiveness of the Choice of Optimum Speed in Shallow Waters

The choice of optimum vessel's speed when sailing in shallow waters, shortening of the distance to be passed through ice-covered areas result in reducing the time under way, saving of fuel consumed under way and cutting of operating expenses during the voyage.

A cut in time under way by 1.0-1.5 days during a round voyage Murmansk - Dudinka - Murmansk in the winter-spring period becomes quite practicable. During the navigation of 1995-1996 the Murmansk Shipping Co. vessels of the atomic barge-carrier "Sevmorput", m/v "Michail Strekalovskiy", m/v "Dmitry Donskoy" types performed 45 voyages.

Comparable data for the transport vessels which were operating in the Arctic, show that the figures of daily working expenses fluctuate within the limits of 5,700-6,800 USD, which will result in final saving of 6,250 USD×45=281,250 USD.

If the average daily fuel consumption under way is 25-30 tons, then saving in fuel cost will be 30×45×80=108,000 USD, where 80 is the price for one ton of heavy fuel in USD in Rotterdam.

Thus, the financial results of fleet operations will be 389,250 USD better on the route Murmansk - Dudinka - Murmansk only.

8. ICE AND NAVIGATIONAL SHIP OBSERVATIONS FOR MORE PRECISE DEFINITION OF NAVIGATION SCENARIOS

The importance of ship ice and navigational observations as compared to the satellite and aircraft methods of ice reconnaissance lies in the fact that these observations cover an entire set of characteristics associated with ice conditions and give a detailed indication of icebreaking capability of ships of one or another ice class.

It is this set of ship ice and navigational observations and of the practical experience gained by the Master V. P. Smirnov in sailing on the nuclear barge-carrier "Sevmorput" and on a number of other ships that has been used as a basis for description of the above scenarios of navigation along the NSR.

GLONASS (Russia) and GPS (USA) satellite navigation systems used for high-accuracy position fixing (to an accuracy of 10 m) as well as logs used for measuring speed made good over the ground (acoustic logs) make it possible to improve substantially accuracy in determination of the navigational parameters and to give an objective description of ice-breaking capability of a ship during independent sailing or sailing under icebreaker assistance.

The use of high-accuracy navigational parameters (ship speed in ice V_i, speed of convoy being escorted by on ice-breaker V_{cy}, coefficient of manoeuvring C_m) with due regard to seasons and types of navigation and the NSR stretches will enable us to specify more precisely the navigational scenarios set forth in the present paper.

In this connection the scenario of ship ice and navigational observations can be described as follows:

- Review of the normative and other documents defining procedure of relevant ship ice and navigational observations;
- Estimation of ice conditions at ship position, made by the navigator;
- Determination of navigational parameters of ice-breaking capability of a ship during independent sailing and sailing under ice-breaker assistance;

- Documenting of the ship ice and navigational observations;
- Recommendations for improvement of the ship ice and navigational observations and processing of their results.

8.1. Normative Documents Defining a Procedure of Ship Ice and Navigational Observations

"Guide to Navigation through the NSR" [1] specifies meteorological and hydrological regime of the Arctic seas, characteristics of snow cover on the seaway throughout the NSR as well as organization of hydrometeorological service. The above "Guide" obliges the Master of a ship in independent sailing along the NSR to notify twice a day (at 00:00 and 12:00) the Marine Operations Headquarters on his position, course, speed, ice conditions, sea state, visibility and weather. When sailing in convoy it is the icebreaker that is obliged to notify on the above details.

"Recommendations for Organizations of the Nautical Service on Board the Merchant Marine Ships" (RSHS-89) [10] define organization of the bridge watch during sailing in ice. The Master or the Chief Mate of a ship sailing in ice exercises ship control while the Mates fulfil nautical duties and keep watch on the ice conditions.

"Regulations for keeping the Logbook" [11] specify the scope of entries on navigational nature. These entries in association with the navigational plotting and information obtained from loggers make it possible to re-establish the ship sailing situation.

"Instructions for Ice Observation from Ships" [12] specify organization, scope and time of hydrometeorological observations to be taken from those ships whose staff includes meteorologists and hydrologists.

Examination of these normative documents in relation to the ice and navigational observations, show:

- the "Guide" [1] fixes the time of ship report on ice conditions, but the information furnished twice a day cannot represent changes in ice conditions over the interval between the report;

- the "Recommendations" [10] suggest that ice observations are to be taken by the Mates. Meanwhile, the basic principles of representing ice conditions in the logbook and on the navigational charts are not established;
- the "Regulations" [11], as far as they relate to the entry of ice conditions, require to indicate only one parameter: ice concentration;
- the "Instructions" [12] specify additional scope of ice observations and transfer the results to the Marine Operations Headquarters, Ice Center (AARI) every 4 hours. These operations are to be performed by the hydrologists provided only on the staffs of icebreakers or by the AARI's specialists.

8.2. Basic Principles behind Organization of the Ship Ice and Navigational Observations

The proposed organization of the ship observations, reporting and processing of ice and navigational data is based on improvement of the existing system in consideration of the capabilities of the modern electronic facilities as well as representation of the ice conditions on the electronic charts and transfer of the data to the shore:

Implementation of such organization against the background of growth in the large-scale freight traffic along the NSR, will make it possible:

- to ensure a flow of ice and navigational information from ship on a scale close to real time;
- to use data on ice and navigational conditions available from ships in making ice forecasts and to increase thereby the probability of their justification;
- to improve the navigational scenario through refinement of the indices and criteria of its evaluation.

The principles behind organization of the ship ice and navigational observations proceed from a simple fact that the observations are of great importance for nautical navigation. The scope of observations includes the indispensable list of six ice characteristics of navigational significance: ice concentration, age (thickness), forms, decay, hummock, compacting. The results of observations taken within a watch-keeping period are conveyed, using the International Symbol System [13] (Fig. 7), in one of the following ways:

1) by text (existing),

2) by tables (proposed by AARI) and
3) by electronic charts (proposed by CNIIMF).

The first two ways of conveying data may be used right now; the last version - with the use of electronic chart may be implemented as the electronic charts are adopted on board ships and the appropriate program of electronic service developed.

8.3. Ice and Navigational Ship Observation

Ice concentration is assessed as both the total and partial concentration. The total concentration is determined by 10-point scale. The partial concentration of multi-year, first-year and young ice is determined as a part of the total ice concentration. The above concentration is also expressed in scale units, e.g. total concentration is 8/10, of which 1/10 refers to the multi-year ice, 3/10 - to the first-year and 4/10 - to the young ice.

Ice age is designated by digital symbols, e.g. multi-year ice (9), first-year old ice (7), and young ice of 15-30 cm thick (5).

Ice forms are designated by digital symbols, e.g. multi-year old ice floes of 100-500 m (4), young ice floes of 20-100 m in size (3), first-year old ice floes of 100-500 m (4), young ice floes of 0,5-2 km in size (5).

Ice decay is designated by a symbol or digit describing decay (during the melting period) of ice with concentration of 7/10 - 10/10. For example, decay of dried ice is marked by a digit (6).

Hummock is marked by a separate symbol or digit on 5-point scale. The hummock of ice is defined at its concentration of 7/10-10/10. For example, in case where three ridges are observed over a mile, the hummock is designated by a two-digit pair (3/5).

Ice compacting is assessed by a symbol and digit on three-point scale. Compacting of ice is defined at its concentration of 7/10-10/10. For example, ice under low pressure is marked by a symbol →1← or by two-digit pair (1/3).

Additional data include: time, co-ordinates, course, speed, distance made good within a watch-keeping period as measured by the log, wind, air temperature, way of escorting ships in ice, e.g. time = 04:00, data = 15.10.98, latitude = 77°50', longitude = 111°20', course = 90°, speed = 8 knots, distance made good within a watch-keeping period as measured by the log = 34 miles, wind = 135° - 7 m/s, T_{a} = -15° , independent navigation (1), convoy of 2 ships following in the wake of the icebreaker-leader (1-2), escorting of a ship in tow behind the ice-breaker (1+1).

Forms of reports for the above examples:

- by text: 04:00, 15.10.98., 77.50, 111.20, course 90°, speed 8, distance made good within a watch-keeping period as measured by the log 34, total concentration 8/10, of which 1/10 refers to the multi-year ice, 3/10 - to the first year ice and 4/10 - to the young ice, thickness of the young ice 30 cm, form of the multi-year ice 3, the first-year ice 4, the young ice 5, ice decay 6, hummock 3/5, compacting 1/3, wind 135°-7, air temperature -15°C, convoy of 2 ships following in the wake of the icebreaker. Master of the m/s "Dimity Donskoy".
- by table (columns 1-23) : 1-04:00, 2-15.10.98, 3-77 50, 4-111 20, 5-90, 6-8, 7-34, 8-8/10, 9-1/10, 10-3/10, 11-4/10, 12-30, 13-3, 14-4, 15-5, 16-6, 17-3/5, 18-1/3, 19-135-7, 20--15, 21-1-2, 23-0. Master of the m/s "Dimity Donskoy".
- by electronic chart (a fragment of the chart is given on Fig.8) marked on the ship track at point 04:00 are time, data, latitude, longitude; introduced into the oval sign are ice characteristics (concentration, age, form). The oval sign is positioned on that side of the ship track where the larger portion of ice concentration is observed. Ice decay, hummock, compacting, wind, air temperature are marked by relevant symbols nearly the oval sign. Hourly points, ship speed, changes in ice characteristics, way of ship escorting in ice are marked additionally on the ship track.

Reports in correspondence with all forms are sent every 4 hours (within a watch-keeping period). If during this period of time changes have been observed in ice and navigational data, the report is to additionally include time and new characteristic of the ice and navigational situation.

Addresses of the reports include the ship owner, Marine Operations Headquarters and Center of Information on Arctic Shipping.

Processing of data on ice and navigational situation is performed by the specialists of the Center of Information on Arctic Shipping:

The ship velocity in ice V_i and V_{cy} is picked from the textual or tabular reports or read out of the electronic chart. According to section 2.1, the coefficient of ship velocity in ice C_i is estimated as $C_i = V_i / V_c = 10 / 15.2 = 0.65$ and the coefficient of ship velocity in a convoy $C_{cy} = V_{cy} / V_c = 8 / 15.2 = 0.53$.For calculating the coefficient of manoeuvring C_m, the distance made good within a watch-keeping period as measured by the log S_i is picked from the textual and tabular reports and the navigational length of this stretch over the open water is calculated using the position co-ordinates at 00:00 and 04:00 for this purpose. When using the electronic chart, the value of S_l is determined as a sum of hourly stretches, S_n is determined by measurement of the distance between the points on the ship track at 00:00 and 04:00. Then the coefficient of manoeuvring will be equal to $C_m = S_i / S_n = 34 / 30 = 1.13$.

Recording of calculated data. The data from each report (V_i, V_{cy}, C_i, C_{cy}, C_m) are entered in the table.according to the stretches of the NSR seaway given in Section 5.1 and to the ice concentration gradations: 1/10-3/10, 4/10-6/10, 7/10-8/10, 9/10-10/10. The percentage of observance of one or another ice concentration gradation is also entered in the table.

Consequently, the generalized data are used to specify more precisely the type of navigation, parameters of ice navigation and eventually the quantitative index for assessment of the navigational scenario. The index is expressed in terms of the time required for a ship to cover a relevant ice stretch of the NSR.

Conclusions:

1. Modern shipboard facilities for navigation, observation and communication provide high efficiency in representation and transfer of information on ice and navigational situation. The facilities also improve accuracy in determining parameters of ice-breaking capability of ship and give rise to up-to-date recordkeeping and processing of ship ice and

navigational observations. However, the capabilities of the modern shipboard facilities in describing the ice and navigational situation have not been taken into account in the normative documents in force. For collecting and processing the data of ship ice and navigational observations, a Center of Information on the Arctic Shipping should be set up.

2. The results of ship ice and navigational observations can provide a flow of information on ice and navigational situation on a scale close to real time. These results will increase probability of justification of the ice forecasts and improve the scenario of navigation in the whole.

3. Collection of a great body of data on ship ice and navigational observations will make it possible in the foreseeable future to solve some practical problems. The problems involve planning of voyages according to ship types, locations of icebreakers on the NSR seaways, estimation of the icebreaker fees, substantiation of the marine insurance rates and other commercial issues.

4. Transfer of the ice and navigational information every 4 hours from ships and processing in the Center will require additional financial resources. The organizational and financial matters concerning collection and processing of the ship observation data should be studied additionally.

CONCLUSIONS

1. The research into and working out scenarios of seasonal and year-round navigation along the Northern Sea Route have been made for regional transportation of cargoes and transit sailing as well.

The paper gives attention to:

- traditional transport routes in the Russian Arctic which are characterized by stable functioning of vessels during summer and prolonged Arctic navigation;
- operative transport vessels of Arctic sailing; the nuclear barge-carrier "Sevmorput" and motor-vessels "Norilsk", "Michail Strekalovsky" and "Dmitry Donskoy", all of which have technical characteristics close to those of the estimated types of vessels mentioned in the task to this project. The choice of operative vessels allows us to make systematization of qualitative and quantitative factors of scenarios depending on the results of actual observations;
- routes of sailing which correspond to those chosen in the WP1 Project.

The coefficient of cruising speed reduction, depending on ice conditions during navigation, has been chosen as a qualitative factor for the assessment of scenario.

The time (in days) required for passing through an ice-covered stretch of the route has been chosen as a quantitative factor for the assessment of scenario.

2. Scenarios of regional cargo transportation in the Western region of the Arctic have been worked out for the main transportation route: Murmansk-Dudinka-Murmansk along which year-round navigation has been effected since 1979.

Scenario for summer, prolonged and winter-spring periods of navigation have been worked out for the above route, too.

The results of the research into this route are characterized by the following figures showing increase in the steaming time T_{st} depending on the periods of navigation:

- In summer period, an increase T_{st} does not exceed 10-15%, i.e. a transport vessel proceeds practically at a speed close to the cruising one. Thus, it becomes possible to organize a liner schedule for vessels serving container-carrying lines (Arkhangelsk - Dudinka - Arkhangelsk) and rhythmic export of ores and various products on the Murmansk - Dudinka - Murmansk line.

- In prolonged period, as has been proved by the work of the Murmansk Shipping Co. vessels, icebreaker assistance makes liner schedule on the above line possible too. An increase in the steaming component of a voyage time in total - T_{st} by 50-70% will require an additional number of vessels only during prolonged navigation characterized by heavy ice conditions.

- The losses of steaming time T_{st} in winter-spring periods are considerable. The time required for passing through an ice-covered stretch of the route may be increased by 2.2-2.5 times which, in its turn, requires an additional number of vessels to effect the actual volumes of transportation. Icebreaker assistance becomes indispensable during the whole voyage and mooring operations in port, considerably increasing voyage expenses.

3. Scenarios of regional transportation in the eastern region of the Arctic have been worked out for the most important transport route: Vladivostok - Pevek -Vladivostok. Transport operations along this route are mostly effected in the period of summer navigation. Light, medium and heavy ice conditions are typical of this period.
The results of the research into this route show the causes of increase in the steaming time depending on periods of navigation:

- during light navigation vessels proceed to the port Pevek at a cruising speed that may be reduced to a manoeuvring speed when passing through the ice-covered stretches, i.e. during unassisted sailing;

- during medium navigation passing through ice-covered stretches is effected by icebreaker leading, especially in the initial and final periods of navigation;

- during heavy navigation sailing along the route from Cape Dezhnev to the port Pevek is effected by icebreaker leading.

The calculations show that depending on the types of navigation an increase in the steaming time ΔT_{st} is:

- light navigation - 10-15%,

- medium navigation - 20-35%,
- heavy navigation - 35-70%.

In prolonged periods of navigation, northerly winds give rise to ice compression and even nuclear icebreakers are not capable to pass through the stretches obstructed with pack ice especially in the eastern part of the route.

4. Scenarios of transit navigation development have been considered for the periods of summer and prolonged navigation along two routes for individual transport vessels and convoys:

- coastal (Southern Arctic),
- high-latitudinal (Northern Arctic).

Transit cargo transportation along the NSR must meet the following requirements:

- regularity and reliability of Arctic transportation;
- safety of vessels and their cargoes;
- saving of steaming time as compared with transportation effected by traditional southern seaway.

The calculations show that an increase in the steaming time in transit sailing will be as much as 10-20% in light and medium navigation and 25-45% in heavy ice navigation.

Comparative calculations made for a transit passage from West European ports to the East (Hamburg - Murmansk - the NSR - Yokohama) show a considerable saving of time even in the periods of summer navigation in heavy ice conditions.
Expenses on icebreaker leading are considerably lower as compared with the rates of tariffs for passing through the Panama or Suez canals, pilot fees and time wasted in waiting one's turn for passing through the above canals.
However, it should be born in mind that the experience gained in organization of transit passages along high-latitudinal routes is yet insufficient to speak of reliable year-round transit navigation.

5. The research made by V. Smirnov has shown a decrease in the draft of transport vessels

when sailing in ice conditions over shallow depths. Special ice-tests and subsequent registration of data on the water-ice-draft change in the ice passport of each transport vessel will enable her master: to correctly determine her draft when the ship are sailing through ice fields in shallow waters; to increase the vessel's load draft within estimated limits and to ensure safe sailing.

Further steps aimed at collecting and systematizing information for scenarios, working out models of the expected results for particular voyages will contribute to a higher degree of effectiveness of transportation along the NSR. The above transportation make use of technical and scientific achievements including types of vessels and icebreakers, expansion of the program of experimental voyages and improvements in the system of navigational and hydrometeorological assistance.

6. The analysis of ship ice and navigational observations shows that the use of the modern shipboard facilities for navigation, observation and communication will improve considerably the completeness and quality of generation of an information base for ice and navigational conditions. Processing of this information in the Center of Information on the Arctic Shipping will make it possible: to supplement the data base on icebreaking capabilities of ships, according to the tonnage groups and propulsive outputs; to upgrade the quality of ice forecasts and to improve thereby the navigational scenario as a whole.

Collection of a great body of data on ship ice and navigational observations will enable us in the foreseeable future to solve practical problems concerning: planning of voyages according to ship types, stationing of icebreakers on the NSR seaways, estimation of the icebreaker fees, substantiation of the marine insurance rates and other commercial issues.

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APPENDICES

Appendix 1.

Technical and Operational Characteristics of Ice-Breakers and Cargo Ice Going Ships

Table A1.1

Basic technical and operational characteristics of ice-breakers

Characteristics	"Arktika"	"Taimyr"	"Kapitan Sorokin"
Length, m	148.0	150.0	134.8
Breadth moulded, m	28.0	28.0	25.6
Depth moulded, m	17.2	15.15	12.3
Summer load- line draft, m	11.0	8.05	8.5
Deadweight, t	4160	705	4840
Displacement, t	23460	18700	16020
Engine type	Nuclear	Nuclear	diesel-electric
Number and output, N kWt	2 x 27500	3 x 12000	6 x 3050
Service speed, knots	21.0	18.5	19.2
Rated ice going capacity, m	2.3	1.8	2.0

Table A1.2

Basic technical and operational characteristics of domestic ice going ships

Characteristics	**LASH carrier "Sevmorput"**	**m/v "Norilsk"**	**m/v "Dmitry Donskoy"**	**m/v "Mikhail Strekalovskiy"**
Ice class	ULA	ULA	UL	UL
Length, m	260.1	173.5	162.1	162.1
Breadth moulded, m	32.2	24.0	22.86	22.86
Depth moulded, m	18.3	15.2	13.5	13.5
Draught, m	11.8	10.5	9.88	9.88
Displacement, t	61880	30760	27340	27340
Deadweight, t	33980	19942	19885	19252
Capacity of containers, TEU	1324	576	442	422
Main machinery unit	Nuclear	LRE	MRE	MRE
Number and output N, kWt	1 x 29420	2 x 7700	1 x 8240	1 x 8240
Service speed, knots	20.0	17.0	15.2	15.2
Rated ice going capacity, m	1.25	0.94	0.74	0.74

Table A1.3

Basic technical and operational characteristics of ice going vessels: multi-purpose ship (SM-15A), container ship (SKN-2600A) and bulk carrier (SN-56A)

Characteristics	SM-15A	SKN-2600A	SN-56A
Ice class	ULA	ULA	ULA
Length, m	159.6	245.0	245.0
Breadth moulded, m	24.0	32.2	32.2
Depth moulded, m	15.2	19.5	18.0
Draught, m	10.5	12.5	12.5
Displacement, t	30760	67540	78840
Deadweight, t	19940	44920	56470
Capacity of containers, TEU	576	2660	-
Main machinery unit, number and output N, kWt	2 x 7700	3 x 17600	17500
Service speed, knots	17.0	24.0	14.9
Rated ice going capacity, m	0.94	1.83	1.0

Appendix 2

Scenario of Hydrometeorological Servicing of Navigation

In planning navigation along the NSR the ship owner (master of a vessel) shall follow the instructions given by the hydrometeorological service for transit sailing along the NSR, stated in the Guide [1, pp.73-80]. The Guide also determines the functions of various Rosgidromet organisations which render their services to shipping in the Arctic.

Mid-term (7-10 days) and long-term (1-6 months) hydrometeorological forecasts are prepared and communicated to users by the State Scientific Centre of the RF - the Arctic and Antarctic Scientific Research Institute (Ice Centre "North", 199397, St. Petersburg, 38 Bering str., fax (812) 352 26 88). Mid-term and long-term hydrometeorological forecasts are drawn up on the basis of long-term hydrometeorological observations and the data on the current hydrometeorological situation.

The sources of current meteorological information are: observation satellites "Ocean" and "Meteor", foreign - NOAA, "Radar sat" and ERS, ice-reconnaissance aircraft, polar stations and automatic ice-buoys. Ice situation is of resolving power of not less than 500 m and the accuracy of geographic tie of 1-2 miles. The international communications satellite INMARSAT is used by the Ice Centre "North" to supply vessels at sea with the forecasts.

The users may receive the following paid information, indicated in Table 1, from the Ice Centre "North":

- ice distribution forecasts for 8 and 30 days in facsimile format which show the state of ice coverage of the Russian Arctic seas;
- forecasts of various ice conditions for 1-3 months which show the periods of stable ice-freezing, formation and destruction of fast shore-ice, clearing from ice etc.
- navigational recommendations which take into account technical capabilities of vessels led by ice-breakers (ice class, displacement, principal dimensions, engine power), give the picture of navigational ice conditions and advise the easiest route in ice.

Table A2.1

Mid-tern and long-term hydrometeorological forecasts, navigational recommendations and their price [6]

NN	Type of information	Approximate price in USD
1.	Ice distribution forecast for 8 days	200
2.	Ice distribution forecast for 30 days	350
3.	Forecast of various ice phenomena for 1-3 months	1500
4.	Navigational recommendations for 8 days	200
5.	Navigational recommendations for 30 days	350
6.	Navigational recommendations for 6 months	1200
7.	The chart of actual ice conditions on a selected route	1200
8.	Meteorological forecast for 10 days	250
9.	Sea level forecast on certain, limited by depth, stretches of the route	200

Navigational recommendations include:

- 8 days charts of ice situation for a certain part of the selected route; the text with navigational recommendations and co-ordinates of the easiest ice route, types of ice-breaker leading and pilot age;
- 30 day forecasts for the whole length of the selected route: type of navigation difficulties, sailing through the stretches of close drift ice (over strength 7) and open ice (strength 3-7), in fast shore-ice; deviations from the selected route in ice-massif areas; speeds of individual vessels and convoys; time total of ice-breaker leading along the route;
- types of navigational difficulties likely to be met during spring, summer and autumn periods for 6 months; times of commencement and end of: ice-breaker sailing, mass ice-breaker leading operations and unassisted sailing; times required for leading along the selected routes.

The Chart of actual ice conditions along the selected route shows the current ice situation registered 1-5 days before the request.

Short-term meteorological forecasts for 1-3 days and the current ice situation are supplied on request on the Marine Operations Headquarters of the Western region of the NSR (port of

Dikson) and for the Eastern region by Marine Operations Headquarters (port of Pevek). Owing to temporary financial pressure in the 1997 navigational period the Marine Operations Headquarters of the Western region of the NSR had residence in the port of Murmansk, and the Marine Operations Headquarters of the Eastern region of the NSR were stationed on board an ice-breaker of the Far-Eastern Shipping Co. Short-term ice and meteorological forecasts are prepared by Scientific-Operational Groups which are included into the Marine Operations Headquarters.

Observations made by observation satellites, polar stations and information received from the Ice Centre "North" are the initial materials for the forecasts. Navigational recommendations regarding the choice of most favourable routes for sailing are prepared on the basis of these forecasts and current meteorological situation and then passed to ice-breaker masters, State Ice Pilots and masters of vessels.

Particular times and volumes of short-term hydrometeorological forecast information are stipulated in the contract for ice-breaker leading which is concluded between the ship owner (ship-master) and ice-breaker operators (the Murmansk or Far-Eastern Shipping companies). The price of the said information is included into the total cost of ice-breaker leading.

Economic effectiveness of hydrometeorological servicing is expressed in cutting transport expenses by not less than 10%. It may be achieved by the choice of the easiest route of sailing in ice and corresponding increase in vessel's speed by 1 knot.

Appendix 3

Designing of Computerised Imitation Models for Merchant Marine Trade on the Base of Acting Fleet in Accordance to Navigation Scenarios

							TABLE	1		
TRADE MODEL FOR VESSEL TYPE					ALV"Sevmorpyt"					
transport scheme				Murmansk-Dudinka-Murmansk						
"Optimistic" prognosis										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	20	20	20	20		20	20	20	20	
Coefficient of speed in ice										
	1	0.9	0.9	0.9		0.9	0.9	0.9	1	
Coefficient of manoeuvring										
	1	1.05	1.05	1.05		1.05	1.05	1.05	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	581	1179	1452		1830	2429	2649	3009	
Real speed, n.miles/vsl-day										
	480	432	432	432		432	432	432	480	
Time of proceeding the link, days										
5	0.75	0.51	1.39	0.63	10	0.88	1.39	0.51	0.75	5
Time of the voyage (integral), days										
5	5.75	6.26	7.65	8.28	18.3	19.2	20.5	21	21.8	26.8
**								******************		
Links of transport scheme & their numbers:										
0	1	2	3	4	5	4	3	2	1	0
**								******************		
"Pessimistic" prognosis:										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	20	20	20	20		20	20	20	20	
Coefficient of speed in ice										
	1	0.4	0.4	0.4		0.4	0.4	0.4	1	
Coefficient of manoeuvring										
	1	1.35	1.35	1.35		1.35	1.35	1.35	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	644	1413	1764		2250	3020	3303	3663	
Real speed, n.miles/vsl-day										
	480	192	192	192		192	192	192	480	
Time of proceeding the link, days										
9	0.75	1.48	4.01	1.83	18	2.53	4.01	1.48	0.75	9
Time of the voyage (integral), days										
9	9.75	11.2	15.2	17.1	35.1	37.6	41.6	43.1	43.8	52.8
Links of transport scheme & their numbers:										
0	-	on bearth at port of Murmansk								
1	-	p.Murmansk-Kolguev isl.								
2	-	Kolguev isl.-Karskie vorota								
3	-	Karskie vorota-Krestovskie isls.								
4	-	Krestovskie isls.-p.Dudinka								
5	-	on bearth at port Dudinka								

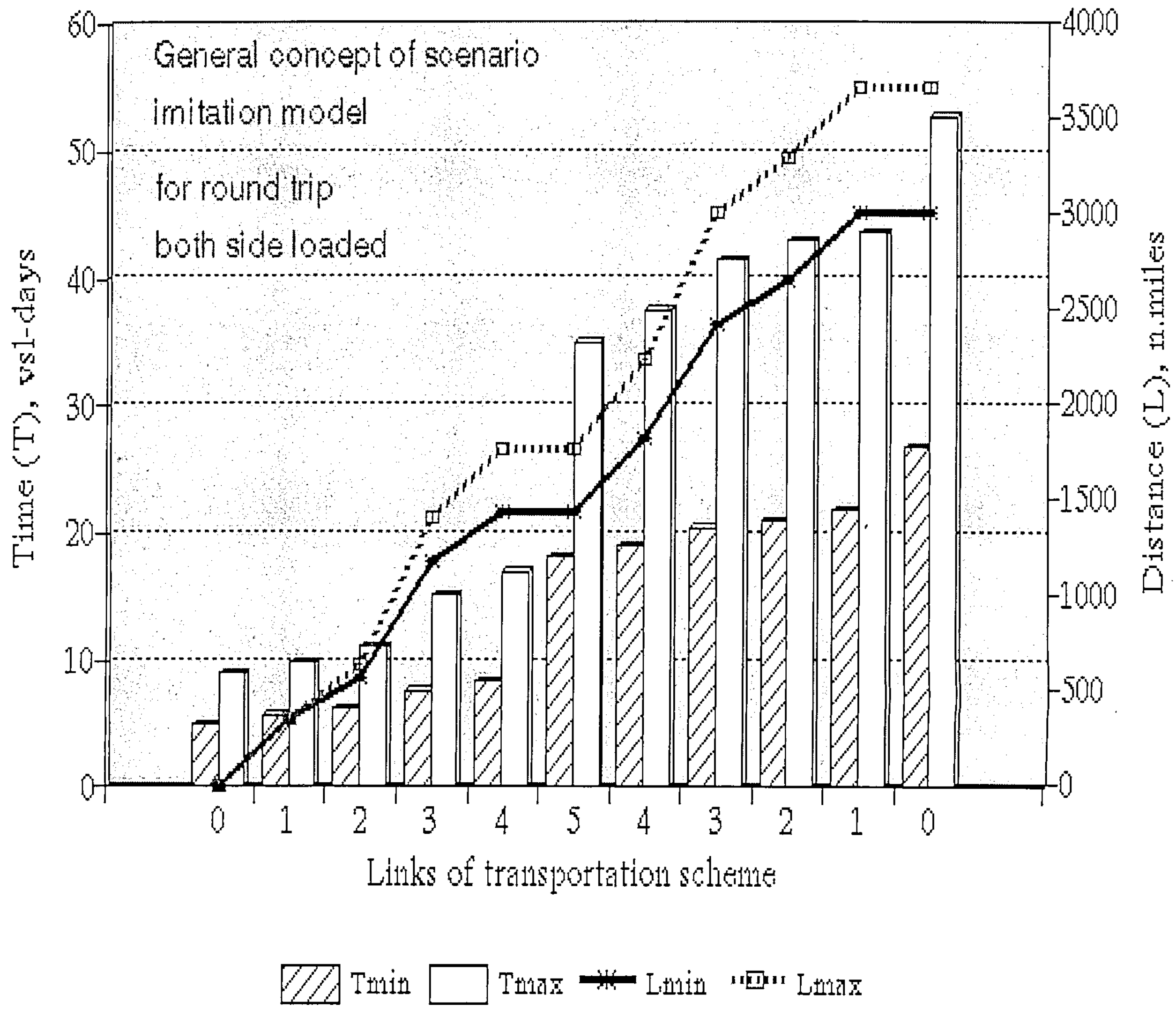


Fig.1 Trade model of ALV"Sevmorpyt" voyage Murmansk-Dudinka-Murmansk.

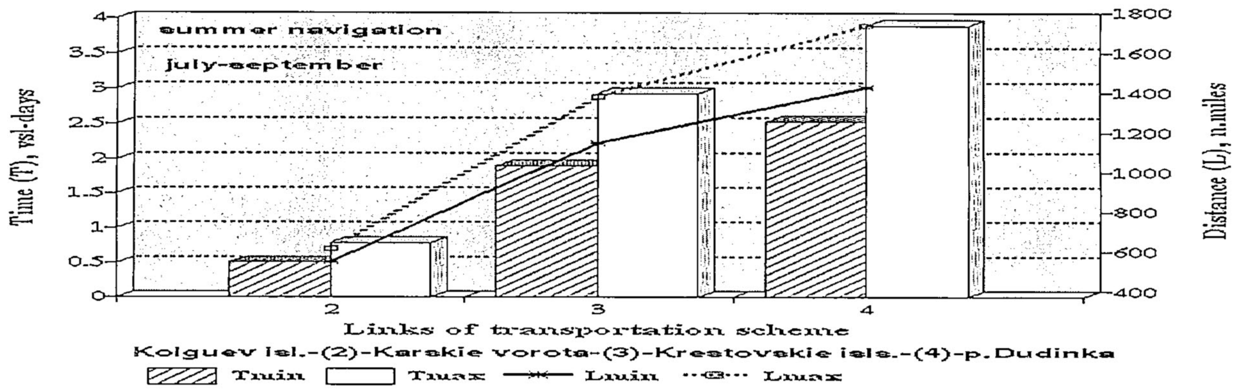


Fig.1.1 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Dudinka.

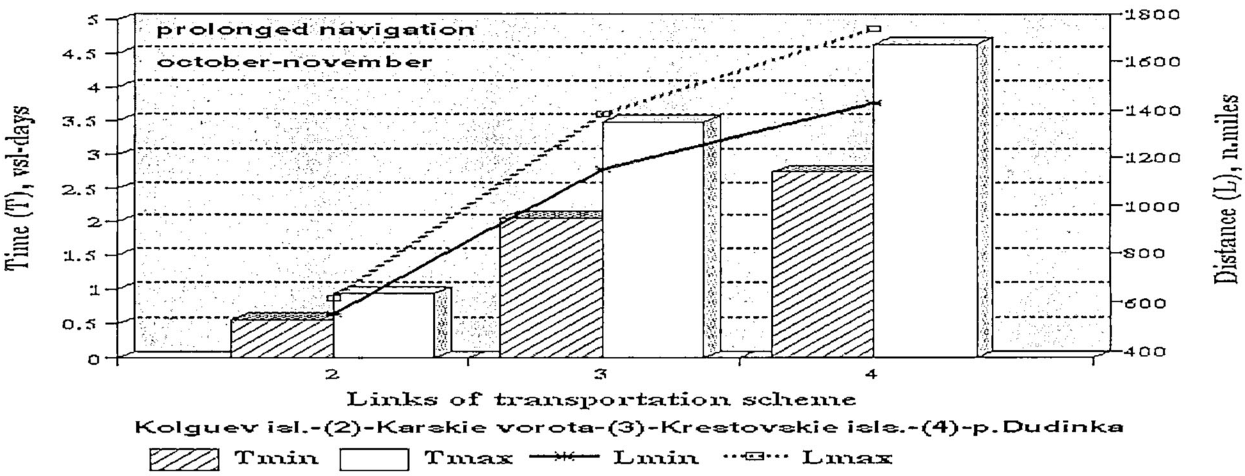


Fig.1.2 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Dudinka.

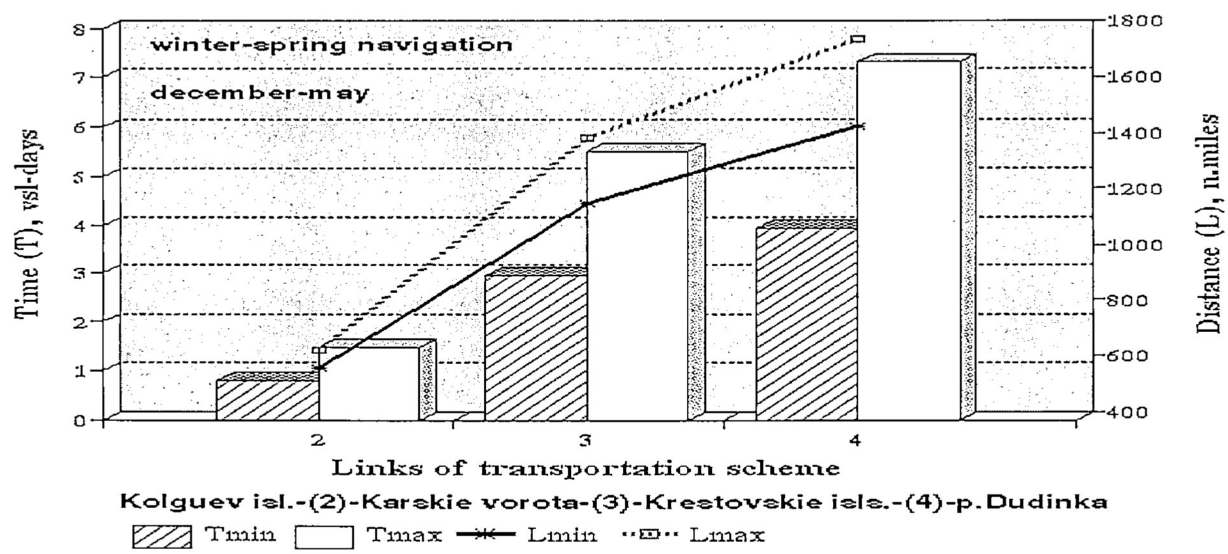


Fig.1.3 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Dudinka.

							TABLE	2		
TRADE MODEL FOR VESSEL TYPE					m/v"Norilsk"					
transport scheme				Murmansk-Dudinka-Murmansk						
"Optimistic" prognosis										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	17	17	17	17		17	17	17	17	
Coefficient of speed in ice										
	1	0.9	0.9	0.9		0.9	0.9	0.9	1	
Coefficient of manoeuvring										
	1	1.05	1.05	1.05		1.05	1.05	1.05	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	581	1179	1452		1830	2429	2649	3009	
Real speed, n.miles/vsl-day										
	408	367	367	367		367	367	367	408	
Time of proceeding the link, days										
6	0.88	0.6	1.63	0.74	12	1.03	1.63	0.6	0.88	6
Time of the voyage (integral), days										
6	6.88	7.48	9.11	9.86	21.9	22.9	24.5	25.1	26	32
**								******************		
Links of transport scheme & their numbers:										
0	1	2	3	4	5	4	3	2	1	0
**								******************		
"Pessimistic" prognosis:										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	17	17	17	17		17	17	17	17	
Coefficient of speed in ice										
	1	0.4	0.4	0.4		0.4	0.4	0.4	1	
Coefficient of manoeuvring										
	1	1.35	1.35	1.35		1.35	1.35	1.35	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	644	1413	1764		2250	3020	3303	3663	
Real speed, n.miles/vsl-day										
	408	163	163	163		163	163	163	408	
Time of proceeding the link, days										
8	0.88	1.74	4.72	2.15	16	2.98	4.72	1.74	0.88	8
Time of the voyage (integral), days										
8	8.88	10.6	15.3	17.5	33.5	36.5	41.2	42.9	43.8	51.8
Links of transport scheme & their numbers:										
0	-	on bearth at port of Murmansk								
1	-	p.Murmansk-Kolguev isl.								
2	-	Kolguev isl.-Karskie vorota								
3	-	Karskie vorota-Krestovskie isls.								
4	-	Krestovskie isls.-p.Dudinka								
5	-	on bearth at port Dudinka								

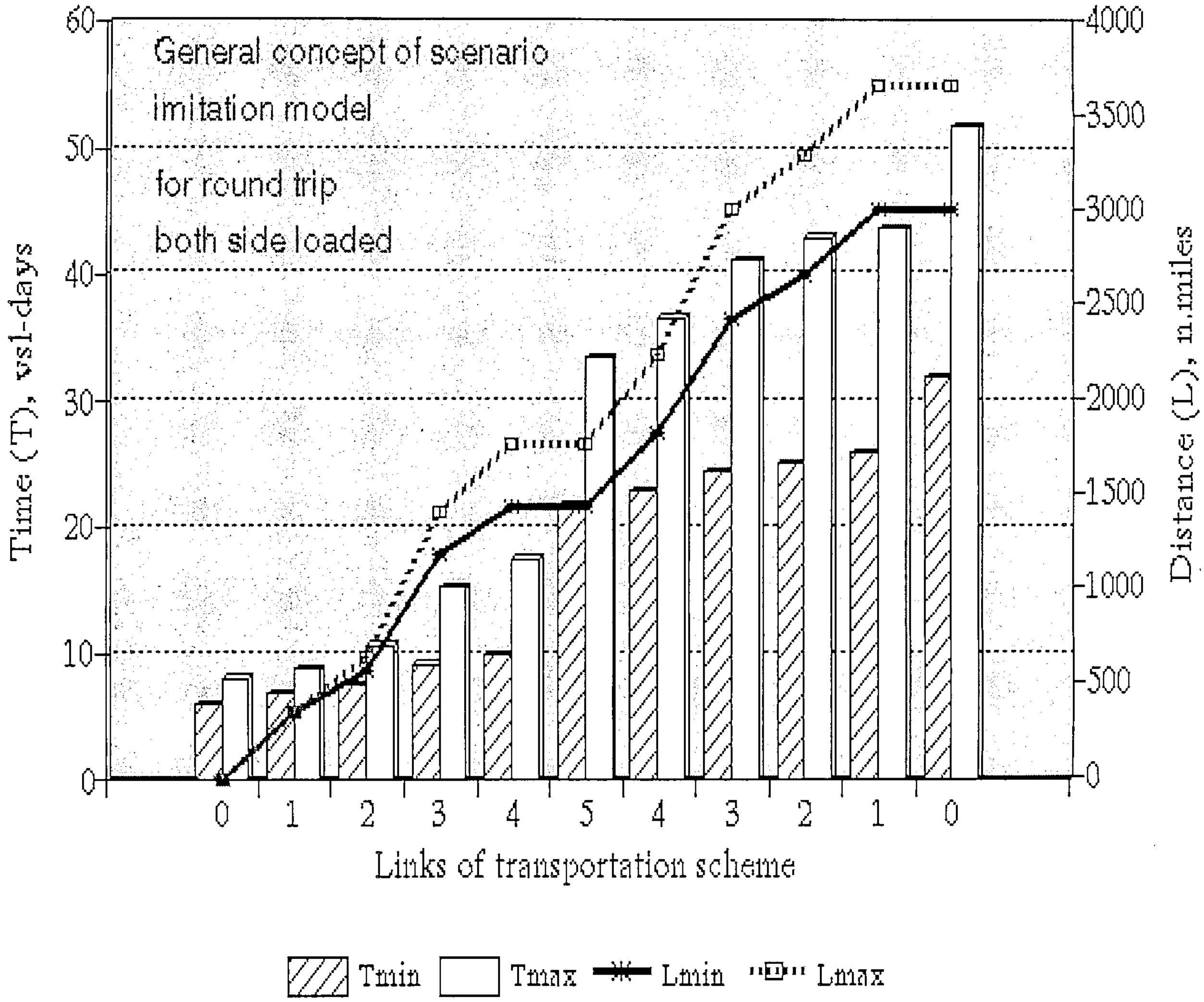


Fig.2 Trade model of m/v"Norilsk"
voyage Murmansk-Dudinka-Murmansk.

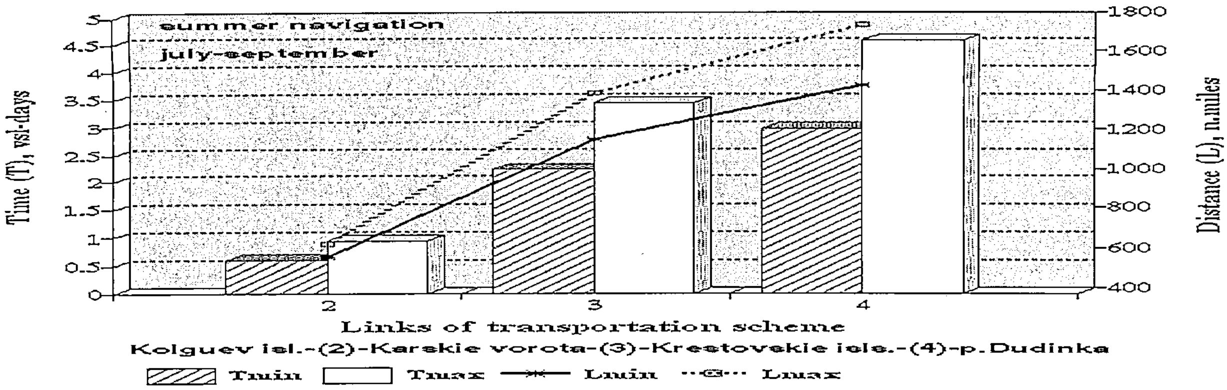


Fig.2.1 Trade model of m/v"Norilsk" ice going on route Murmansk-Dudinka.

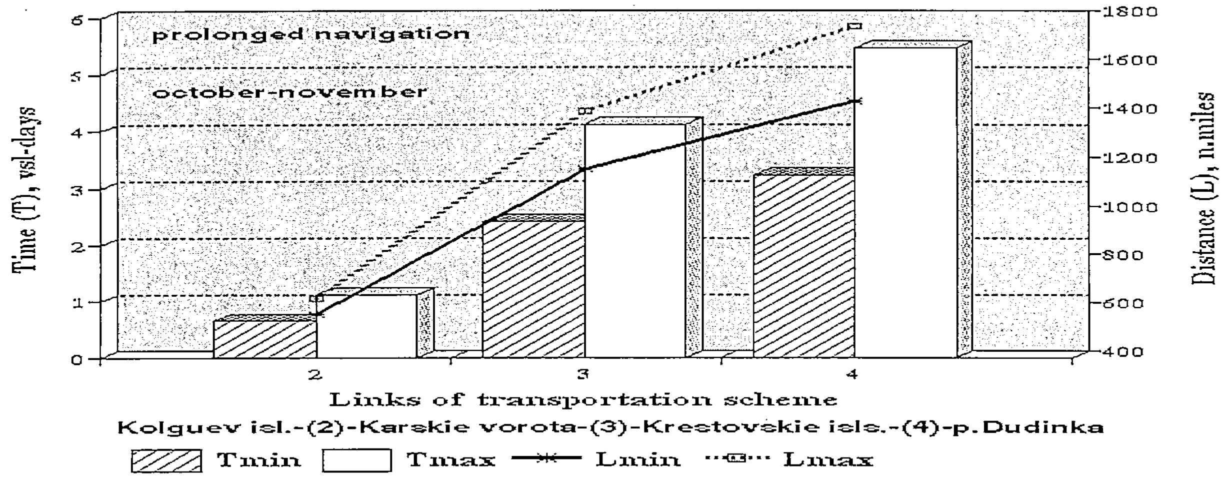


Fig.2.2 Trade model of m/v"Norilsk" ice going on route Murmansk-Dudinka.

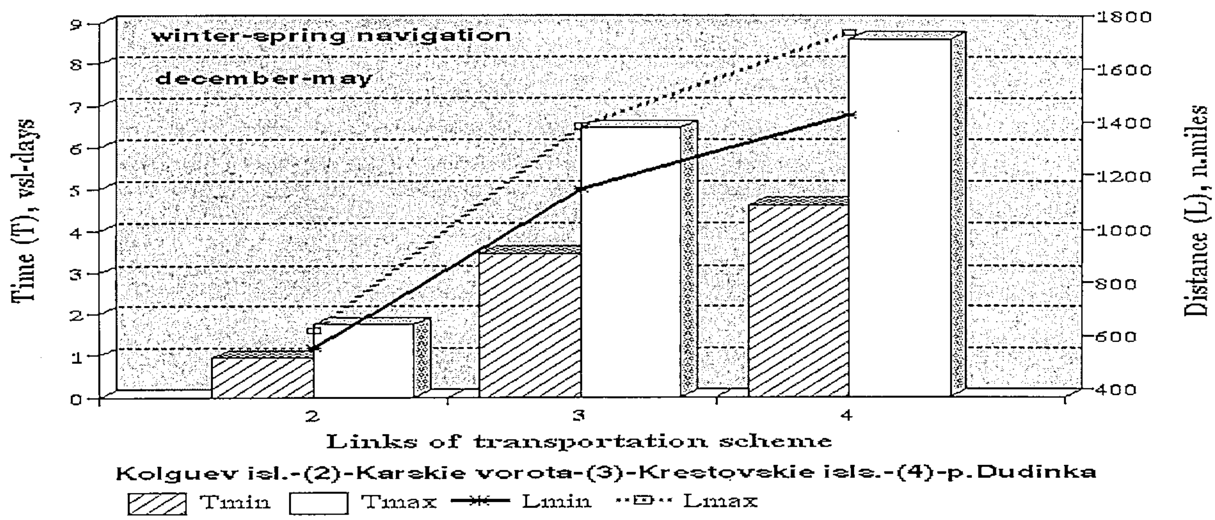


Fig.2.3 Trade model of m/v"Norilsk" ice going on route Murmansk-Dudinka.

							TABLE	3		
TRADE MODEL FOR VESSEL TYPE					m/v"Dm.Donskoy"					
transport scheme				Murmansk-Dudinka-Murmansk						
"Optimistic" prognosis										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	15	15	15	15		15	15	15	15	
Coefficient of speed in ice										
	1	0.9	0.9	0.9		0.9	0.9	0.9	1	
Coefficient of manoeuvring										
	1	1.05	1.05	1.05		1.05	1.05	1.05	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	581	1179	1452		1830	2429	2649	3009	
Real speed, n.miles/vsl-day										
	360	324	324	324		324	324	324	360	
Time of proceeding the link, days										
4	1	0.68	1.85	0.84	8	1.17	1.85	0.68	1	4
Time of the voyage (integral), days										
4	5	5.68	7.53	8.37	16.4	17.5	19.4	20.1	21.1	25.1
**								******************		
Links of transport scheme & their numbers:										
0	1	2	3	4	5	4	3	2	1	0
**								******************		
"Pessimistic" prognosis:										
DATA BASE:										
Distance of link, n.miles										
	360	210	570	260		360	570	210	360	
Service speed, knots										
	15	15	15	15		15	15	15	15	
Coefficient of speed in ice										
	1	0.4	0.4	0.4		0.4	0.4	0.4	1	
Coefficient of manoeuvring										
	1	1.35	1.35	1.35		1.35	1.35	1.35	1	
CALCULATION RESULTS:										
Real distance (integral), n.miles										
	360	644	1413	1764		2250	3020	3303	3663	
Real speed, n.miles/vsl-day										
	360	144	144	144		144	144	144	360	
Time of proceeding the link, days										
7	1	1.97	5.34	2.44	14	3.38	5.34	1.97	1	7
Time of the voyage (integral), days										
7	8	9.97	15.3	17.8	31.8	35.1	40.5	42.4	43.4	50.4
Links of transport scheme & their numbers:										
0	-	on bearth at port of Murmansk								
1	-	p.Murmansk-Kolguev isl.								
2	-	Kolguev isl.-Karskie vorota								
3	-	Karskie vorota-Krestovskie isls.								
4	-	Krestovskie isls.-p.Dudinka								
5	-	on bearth at port Dudinka								

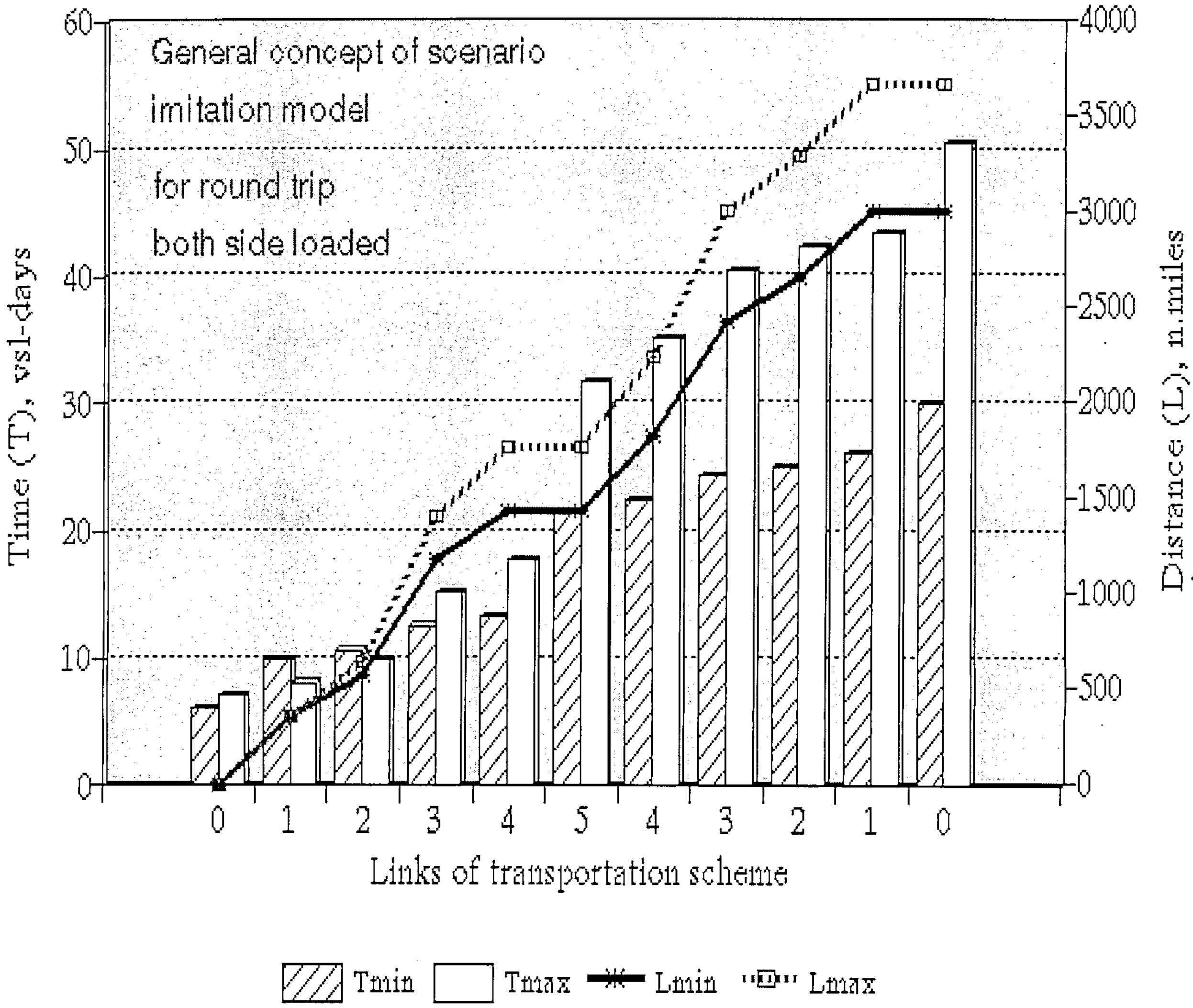


Fig.3 Trade model of m/v"Dm.Donskoy"
voyage Murmansk-Dudinka-Murmansk.

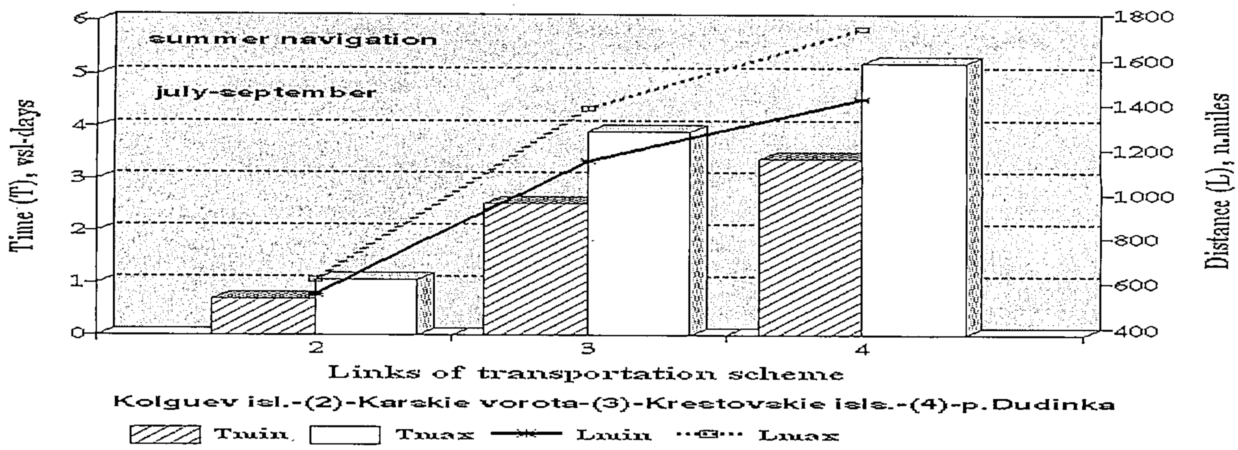


Fig.3.1 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Dudinka.

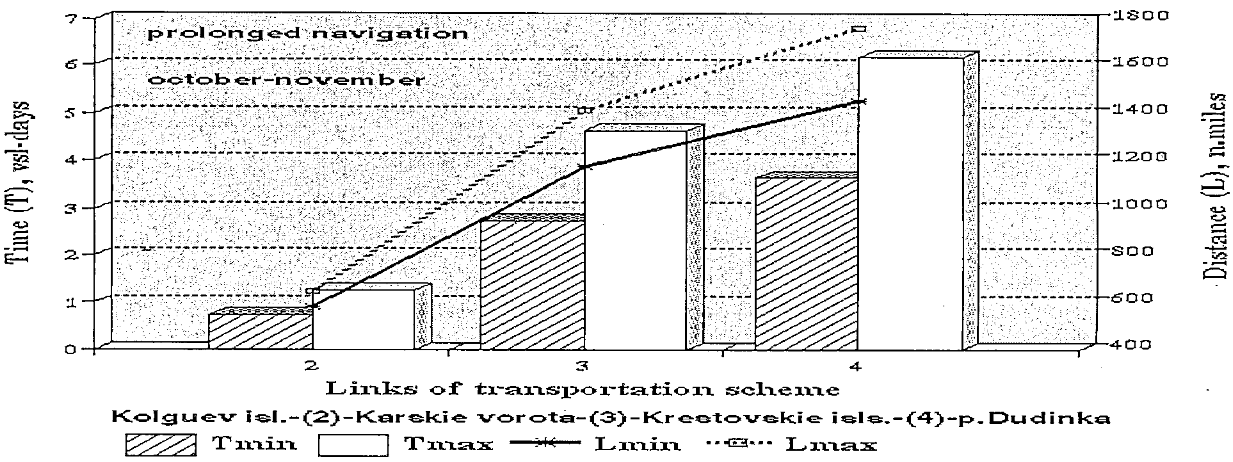


Fig.3.2 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Dudinka.

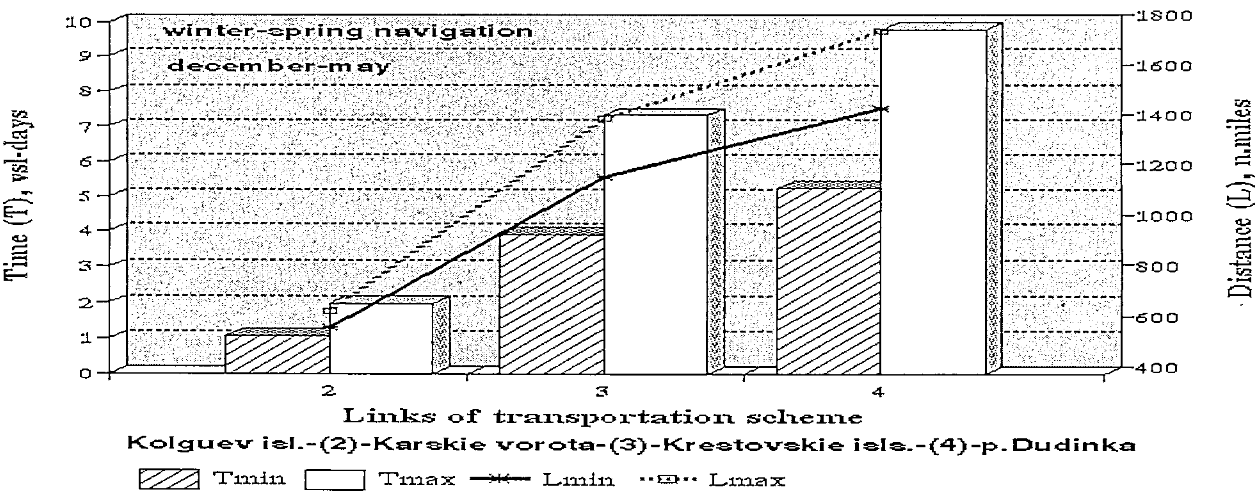


Fig.3.3 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Dudinka.

							TABLE	4	
TRADE MODEL FOR VESSEL TYPE					ALV"Sevmorpyt"				
transport scheme				Vladivostok-Pevek-Vladivostok					
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	20	20	20	20		20	20	20	20
Coefficient of speed in ice									
	1	0.83	0.83	0.83		0.83	0.83	0.83	1
Coefficient of manoeuvring									
	1	1.1	1.1	1.1		1.1	1.1	1.1	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2854	3030	3074		3118	3294	3448	6148
Real speed, n.miles/vsl-day									
	480	398	398	398		398	398	398	480
Time of proceeding the link, days									
5	5.63	0.39	0.44	0.11	5	0.11	0.44	0.39	5.63
Time of voyage (integral), days									
5	10.6	11	11.5	11.6	16.6	16.7	17.1	17.5	23.1
***								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	4	3	2	1
***								************	
"Pessimistic" prognosis:									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	20	20	20	20		20	20	20	20
Coefficient of speed in ice									
	1	0.45	0.45	0.45		0.45	0.45	0.45	1
Coefficient of manoeuvring									
	1	1.25	1.25	1.25		1.25	1.25	1.25	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2875	3075	3125		3175	3375	3550	6250
Real speed, n.miles/vsl-day									
	480	216	216	216		216	216	216	480
Time of proceeding the link, days									
9	5.63	0.81	0.93	0.23	9	0.23	0.93	0.81	5.63
Time of voyage (integral), days									
9	14.6	15.4	16.4	16.6	25.6	25.8	26.8	27.6	33.2
Links of transport scheme & their numbers:									
0	-	on bearth at port of Vladivostok							
1	-	p.Vladivostok-cape Dezhneva-Koluchin isl.							
2	-	Koluchin isl.-cape Shmidta							
3	-	cape Shmidta-cape Shelagski							
4	-	cape Shelagski-p.Pevek							
5	-	on bearth at port Pevek							

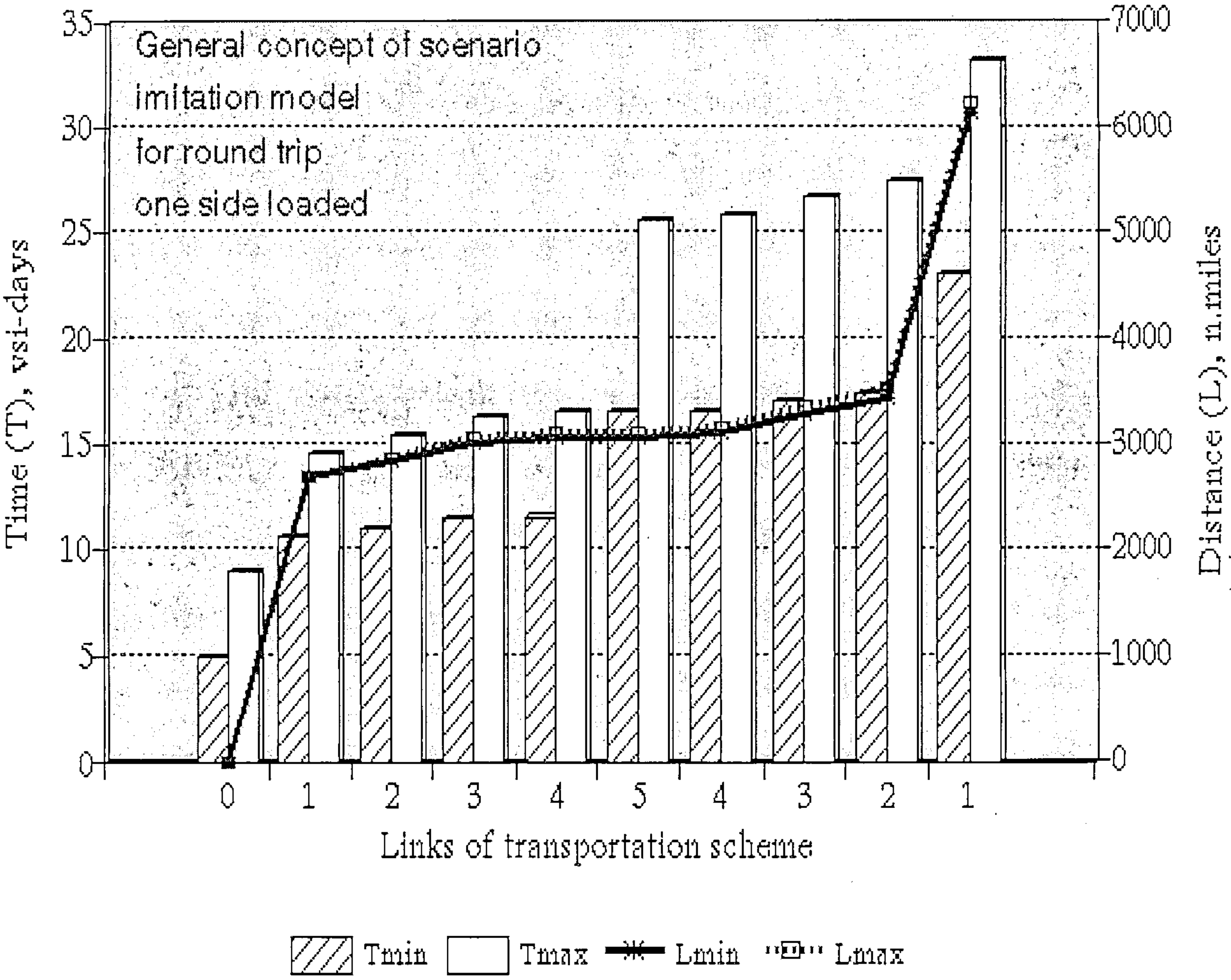


Fig.4 Trade model of ALV"Sevmorpyt"
voyage Vladivostok-Pevek-Vladivostok.

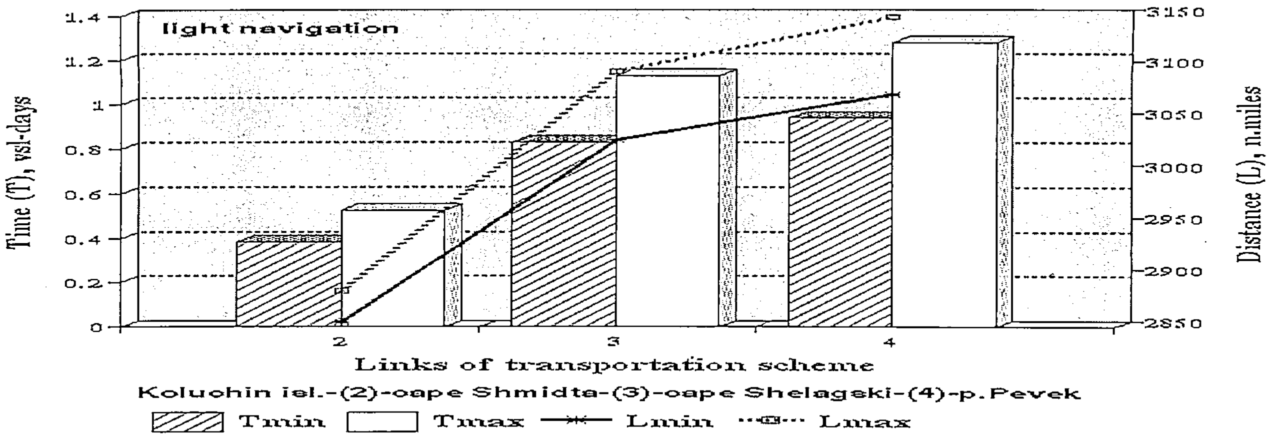


Fig.4.1 Trade model of ALV"Sevmorpyt" ice going on route Vladivostok-Pevek.

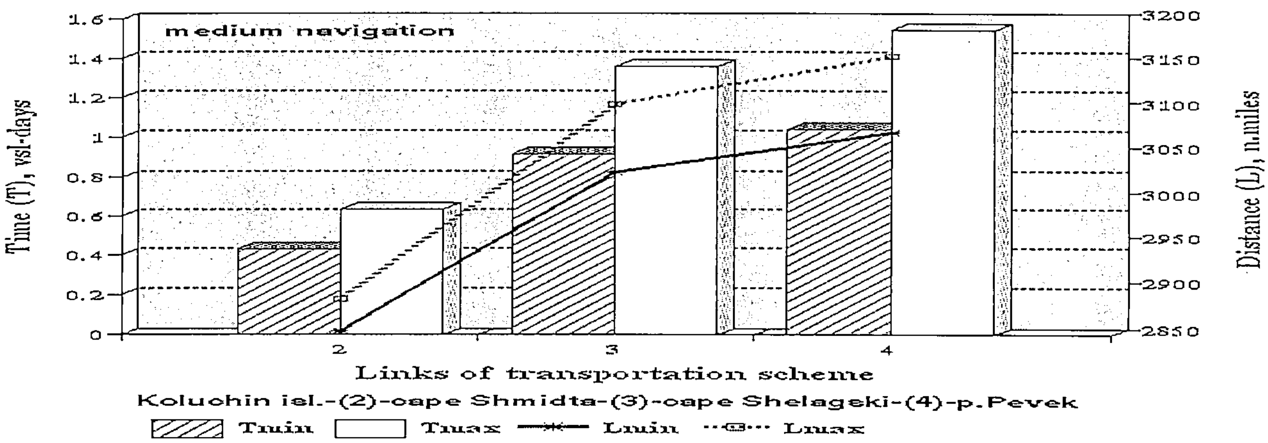


Fig.4.2 Trade model of ALV"Sevmorpyt" ice going on route Vladivostok-Pevek.

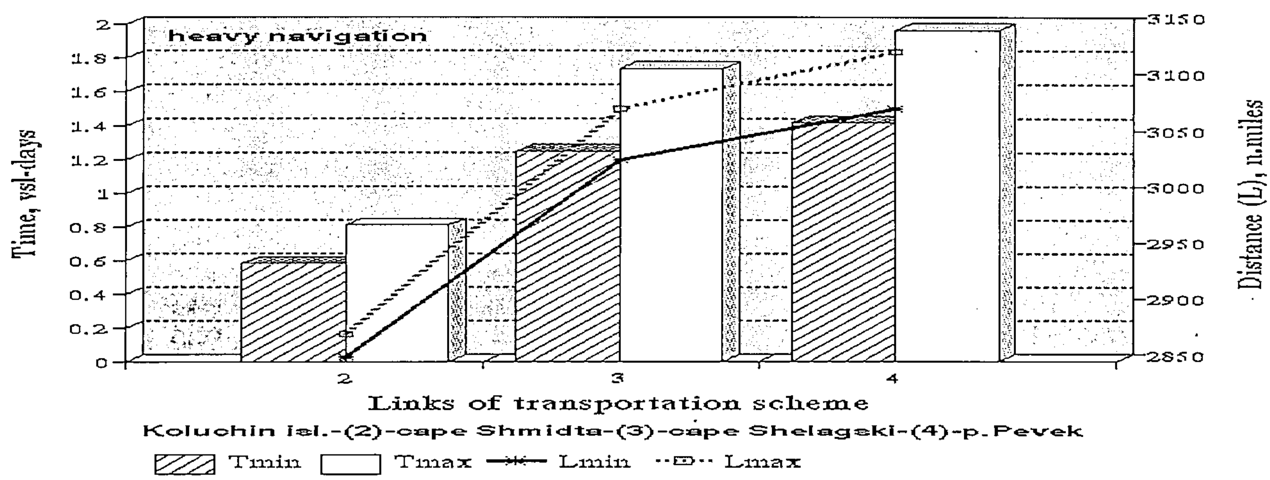


Fig.4.3 Trade model of ALV"Sevmorpyt" ice going on route Vladivostok-Pevek.

							TABLE	5	
TRADE MODEL FOR VESSEL TYPE					m/v"Norilsk"				
transport scheme				Vladivostok-Pevek-Vladivostok					
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	17	17	17	17		17	17	17	17
Coefficient of speed in ice									
	1	0.83	0.83	0.83		0.83	0.83	0.83	1
Coefficient of manoeuvring									
	1	1.1	1.1	1.1		1.1	1.1	1.1	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2854	3030	3074		3118	3294	3448	6148
Real speed, n.miles/vsl-day									
	408	339	339	339		339	339	339	408
Time of proceeding the link, days									
6	6.62	0.45	0.52	0.13	6	0.13	0.52	0.45	6.62
Time of voyage (integral), days									
6	12.6	13.1	13.6	13.7	19.7	19.9	20.4	20.8	27.4
***								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	4	3	2	1
***								************	
"Pessimistic" prognosis:									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	17	17	17	17		17	17	17	17
Coefficient of speed in ice									
	1	0.45	0.45	0.45		0.45	0.45	0.45	1
Coefficient of manoeuvring									
	1	1.25	1.25	1.25		1.25	1.25	1.25	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2875	3075	3125		3175	3375	3550	6250
Real speed, n.miles/vsl-day									
	408	184	184	184		184	184	184	408
Time of proceeding the link, days									
8	6.62	0.95	1.09	0.27	8	0.27	1.09	0.95	6.62
Time of voyage (integral), days									
8	14.6	15.6	16.7	16.9	24.9	25.2	26.3	27.2	33.9
Links of transport scheme & their numbers:									
0	-	on bearth at port of Vladivostok							
1	-	p.Vladivostok-cape Dezhneva-Koluchin isl.							
2	-	Koluchin isl.-cape Shmidta							
3	-	cape Shmidta-cape Shelagski							
4	-	cape Shelagski-p.Pevek							
5	-	on bearth at port Pevek							

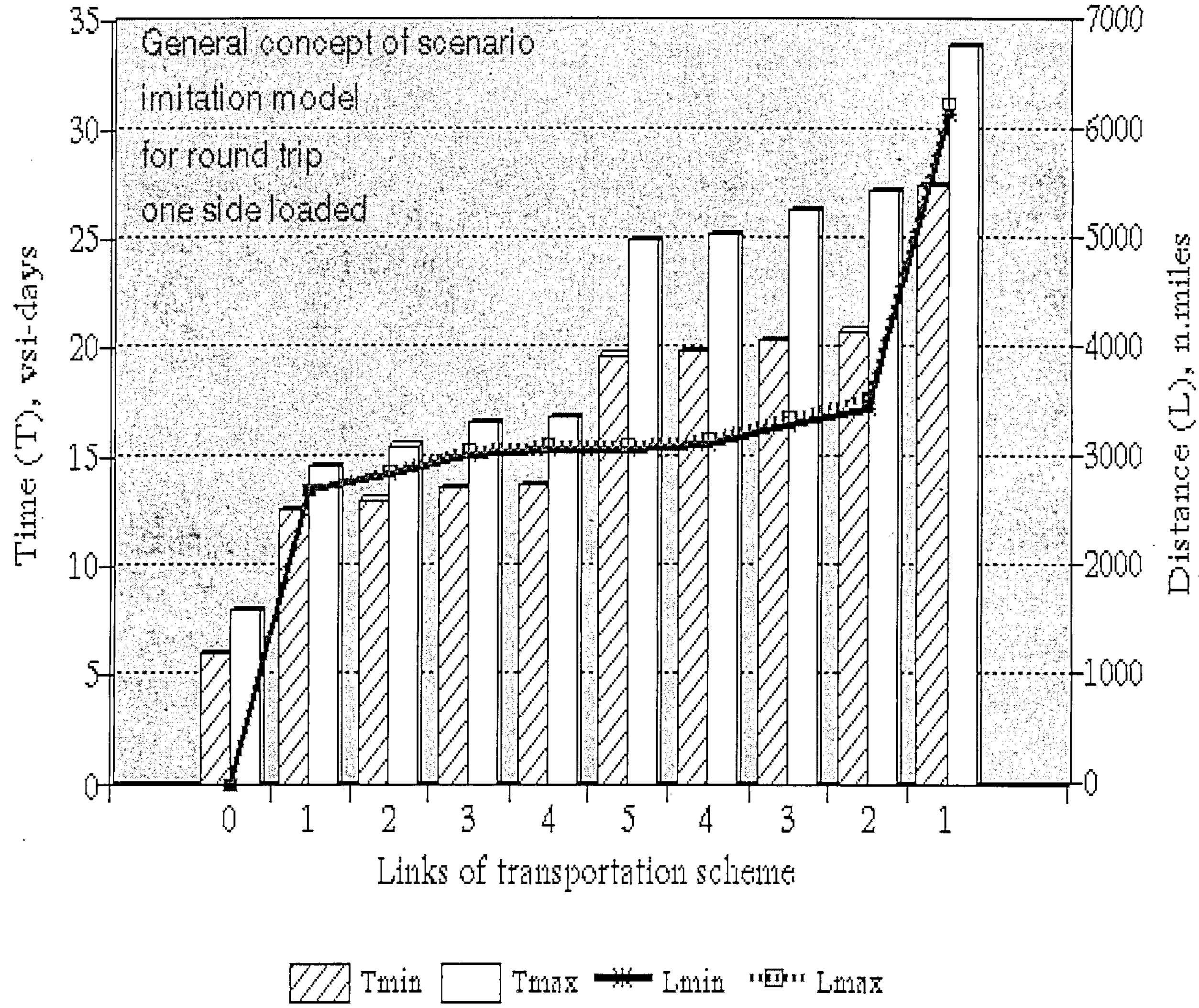


Fig.5 Trade model of m/v"Norilsk"
voyage Vladivostok-Pevek-Vladivostok.

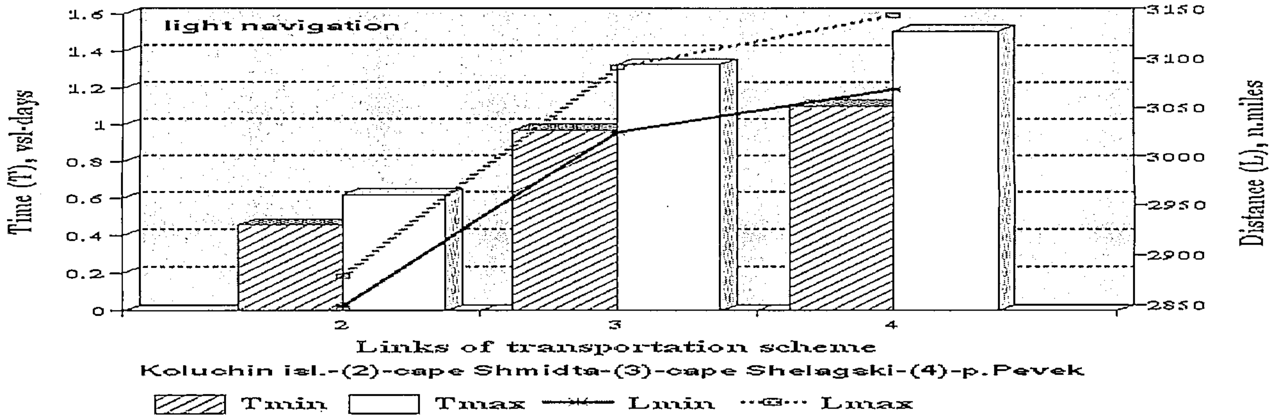


Fig.5.1 Trade model of m/v"Norilsk" ice going on route Vladivostok-Pevek.

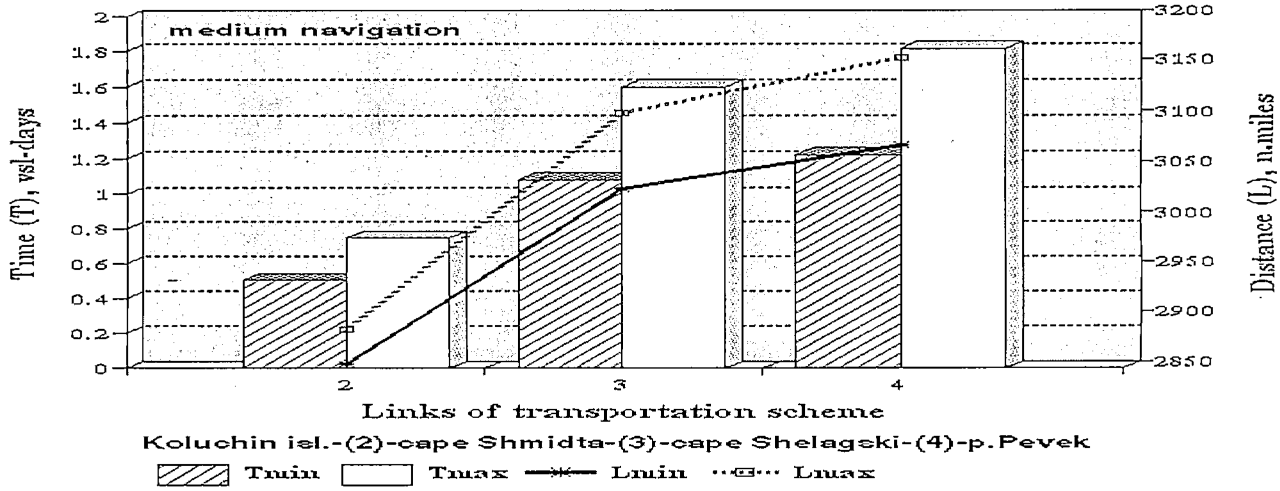


Fig.5.2 Trade model of m/v"Norilsk" ice going on route Vladivostok-Pevek.

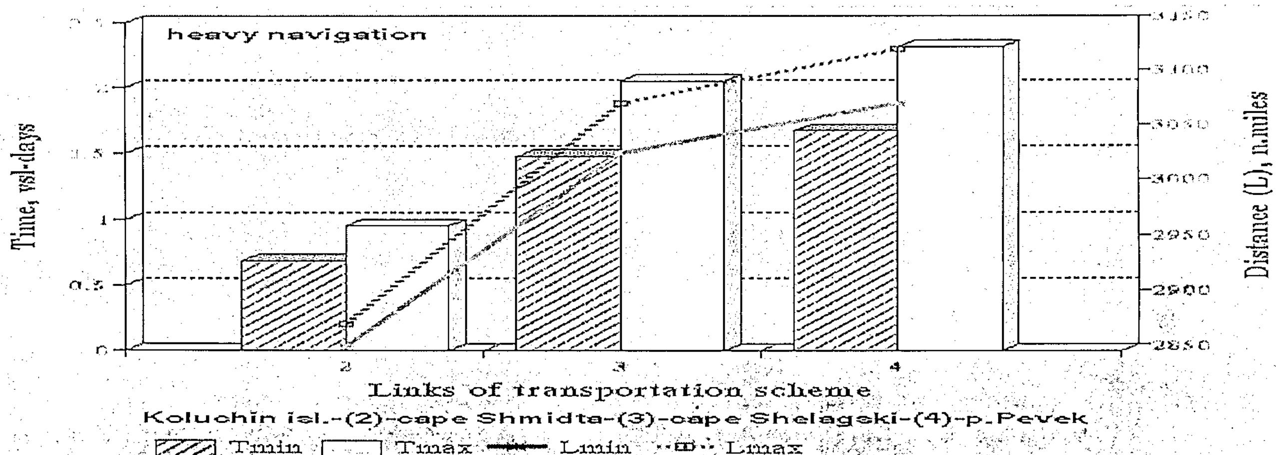


Fig.5.3 Trade model of m/v"Norilsk" ice going on route Vladivostok-Pevek.

							TABLE	6	
TRADE MODEL FOR VESSEL TYPE				m/v"Dm.Donskoy"					
transport scheme			Vladivostok-Pevek-Vladivostok						
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	15	15	15	15		15	15	15	15
Coefficient of speed in ice									
	1	0.83	0.83	0.83		0.83	0.83	0.83	1
Coefficient of manoeuvring									
	1	1.1	1.1	1.1		1.1	1.1	1.1	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2854	3030	3074		3118	3294	3448	6148
Real speed, n.miles/vsl-day									
	360	299	299	299		299	299	299	360
Time of proceeding the link, days									
4	7.5	0.52	0.59	0.15	4	0.15	0.59	0.52	7.5
Time of voyage (integral), days									
4	11.5	12	12.6	12.8	16.8	16.9	17.5	18	25.5
**								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	4	3	2	1
**								************	
"Pessimistic" prognosis:									
DATA BASE:									
Distance of link, n.miles									
	2700	140	160	40		40	160	140	2700
Service speed, knots									
	15	15	15	15		15	15	15	15
Coefficient of speed in ice									
	1	0.45	0.45	0.45		0.45	0.45	0.45	1
Coefficient of manoeuvring									
	1	1.25	1.25	1.25		1.25	1.25	1.25	1
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	2700	2875	3075	3125		3175	3375	3550	6250
Real speed, n.miles/vsl-day									
	360	162	162	162		162	162	162	360
Time of proceeding the link, days									
9	7.5	1.08	1.23	0.31	9	0.31	1.23	1.08	7.5
Time of voyage (integral), days									
9	16.5	17.6	18.8	19.1	28.1	28.4	29.7	30.7	38.2
Links of transport scheme & their numbers:									
0	-	on bearth at port of Vladivostok							
1	-	p.Vladivostok-cape Dezhneva-Koluchin isl.							
2	-	Koluchin isl.-cape Shmidta							
3	-	cape Shmidta-cape Shelagski							
4	-	cape Shelagski-p.Pevek							
5	-	on bearth at port Pevek							

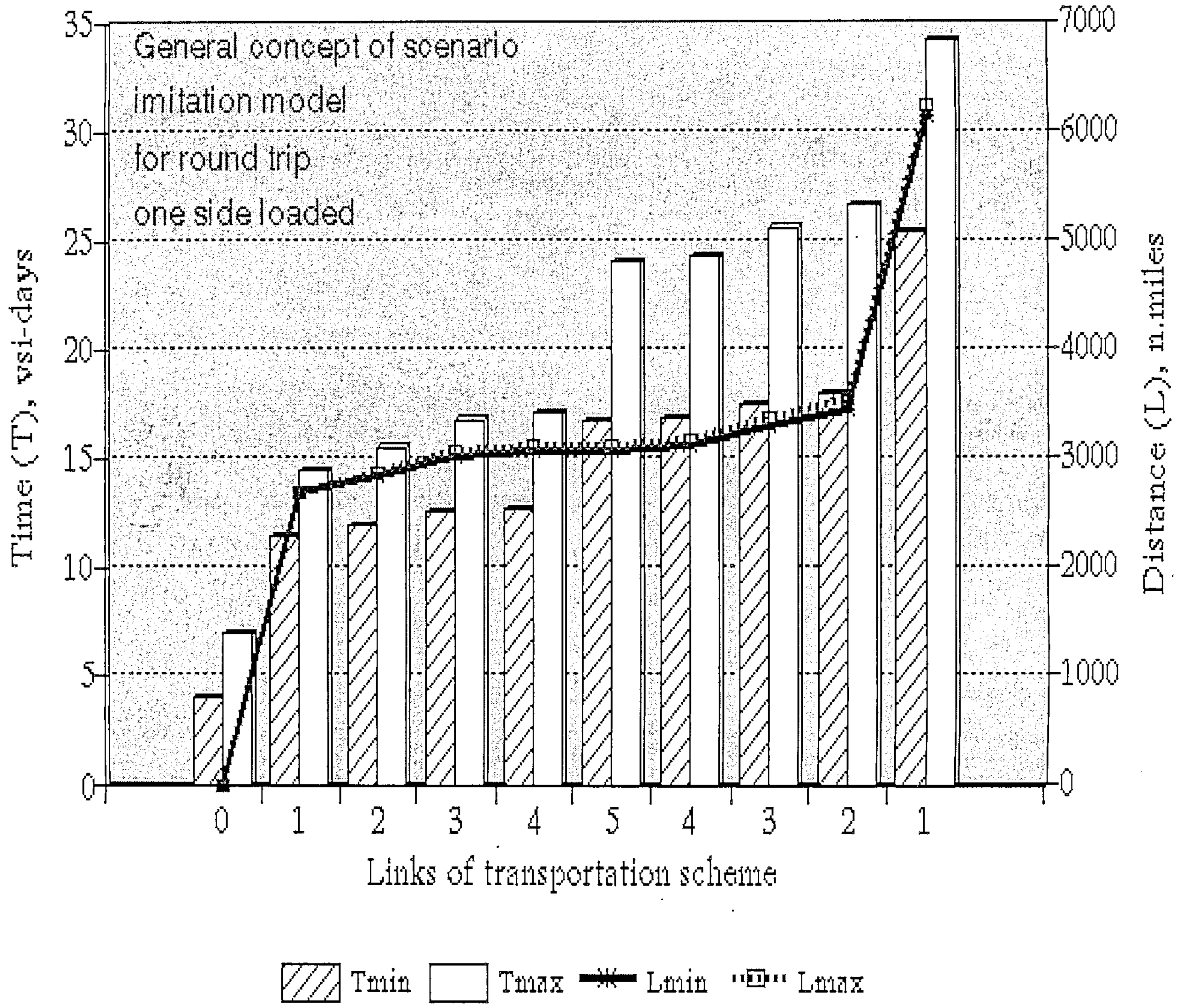


Fig.6 Trade model of m/v"Dm.Donskoy"
voyage Vladivostok-Pevek-Vladivostok.

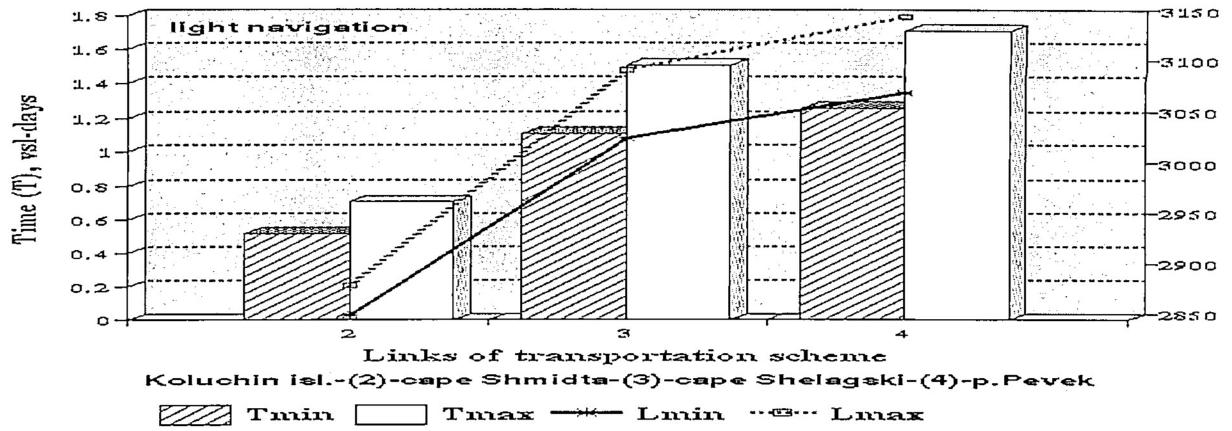


Fig.6.1 Trade model of m/v"Dm.Donskoy" ice going on route Vladivostok-Pevek.

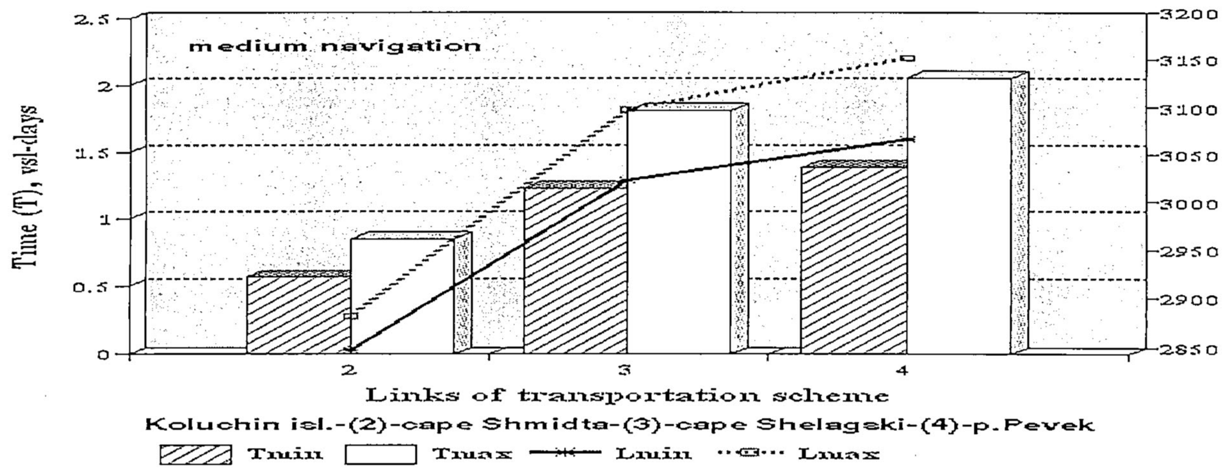


Fig.6.2 Trade model of m/v"Dm.Donskoy" ice going on route Vladivostok-Pevek.

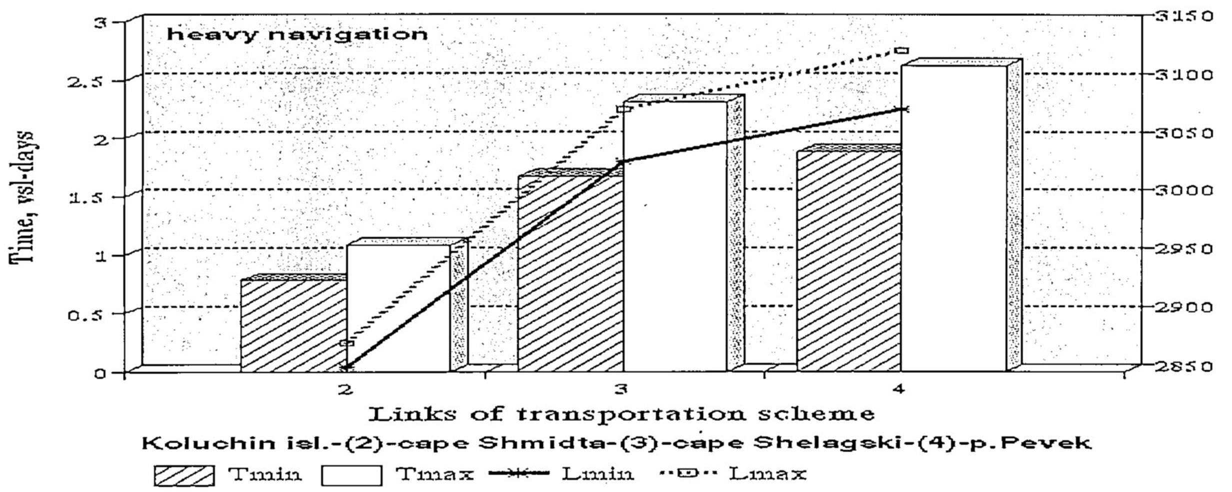


Fig.6.3 Trade model of m/v"Dm.Donskoy" ice going on route Vladivostok-Pevek.

						TABLE	7		
TRADE MODEL FOR VESSEL TYPE					ALV"Sevmorpyt"				
transport scheme				Murmansk-NSR-Vladivostok					
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	20	20	20	20	20	20	20		
Coefficient of speed in ice									
	1	0.88	0.88	0.88	0.88	0.88	1		
Coefficient of manoeuvring									
	1	1.05	1.05	1.05	1.05	1.05	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1087	1472	2045	2738	3069	5769		
Real speed, n.miles/vsl-day									
	480	422	422	422	422	422	480		
Time of proceeding the link, days									
5	1.19	1.22	0.91	1.36	1.64	0.78	5.63	5	
Time of voyage (integral), days									
5	6.19	7.41	8.32	9.68	11.3	12.1	17.7	22.7	
**								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	6	7	8	
**								************	
"Pessimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	20	20	20	20	20	20	20		
Coefficient of speed in ice									
	1	0.52	0.52	0.52	0.52	0.52	1		
Coefficient of manoeuvring									
	1	1.35	1.35	1.35	1.35	1.35	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1234	1730	2467	3358	3783	6483		
Real speed, n.miles/vsl-day									
	480	250	250	250	250	250	480		
Time of proceeding the link, days									
9	1.19	2.66	1.98	2.95	3.57	1.7	5.63	9	
Time of voyage (integral), days									
9	10.2	12.8	14.8	17.8	21.4	23.1	28.7	37.7	
Links of transport scheme & their numbers:									
0	-	on bearth at port of Murmansk							
1	-	p.Murmansk-Karskie vorota							
2	-	Karskie vorota-Dikson isl.							
3	-	Dikson isl.-Vilkitskogo streight							
4	-	Vilkitskogo streight-Medvezhi isls.							
5	-	Medvezhi isls.-cape Shelagski							
6	-	cape Shelagski-Koluchin isl.							
7	-	Koluchin isl.-cape Dezhneva-p.Vladivostok							
8	-	on bearth at port of Vladivostok							

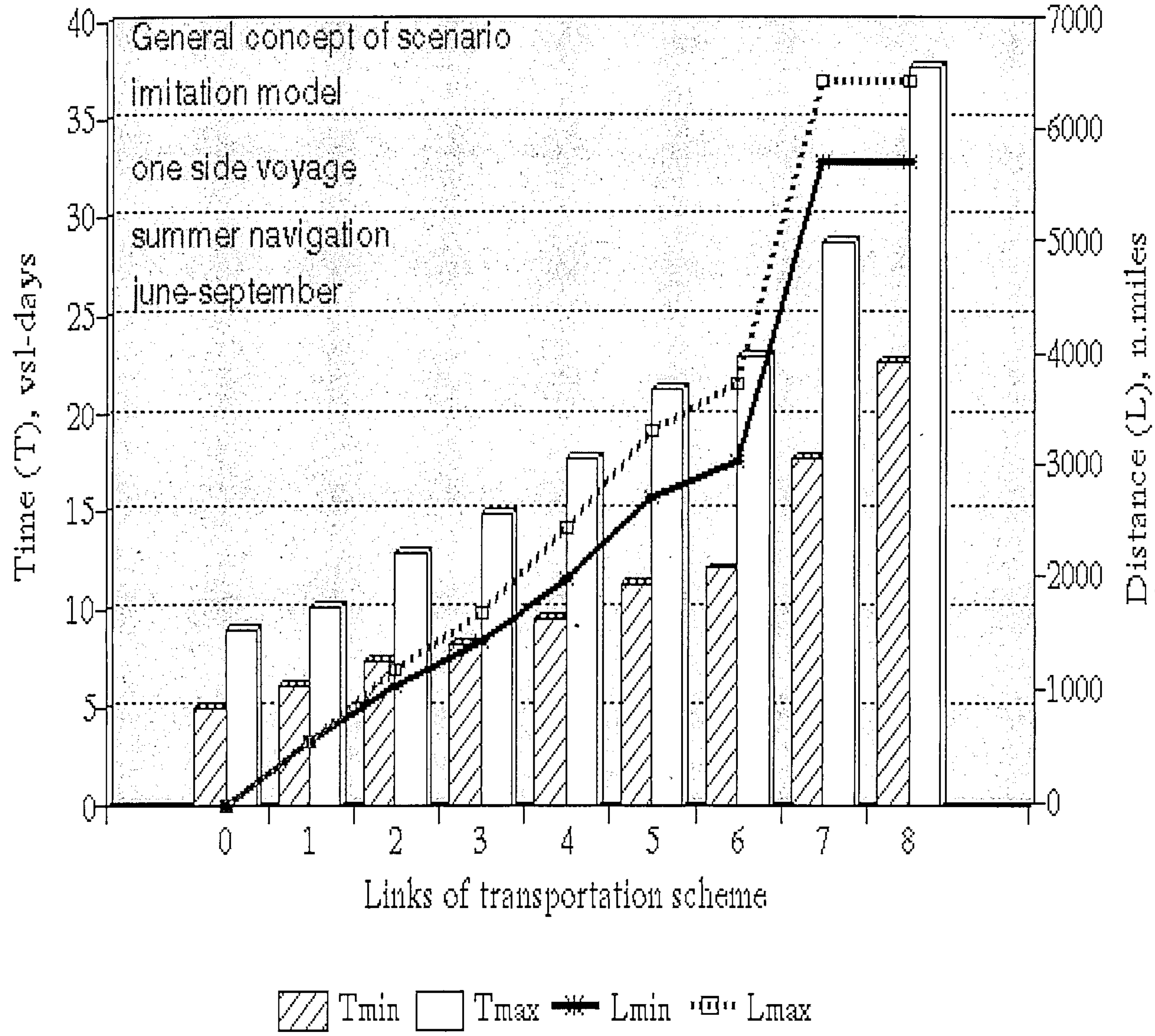


Fig.7 Trade model of ALV"Sevmorpyt"
voyage Murmansk-NSR-Vladivostok.

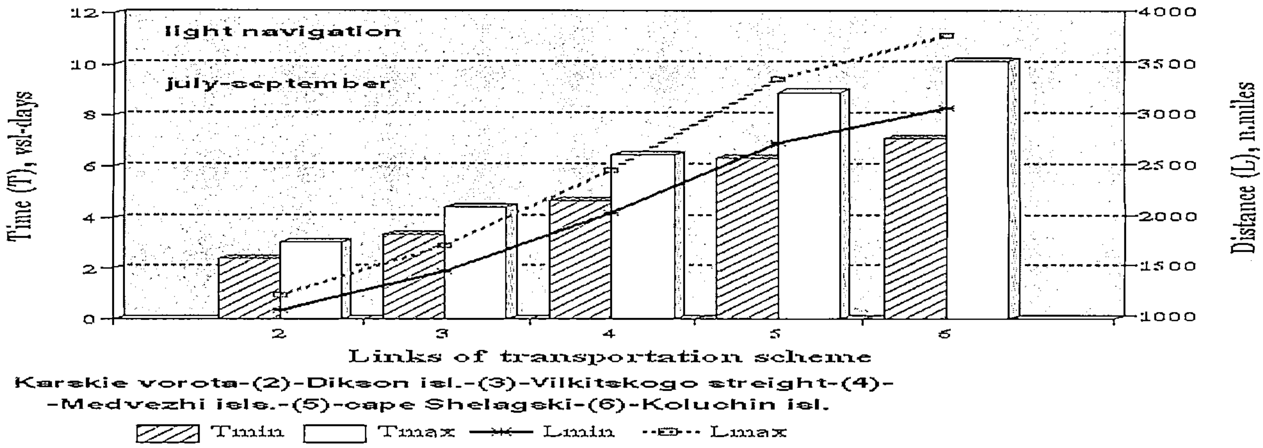


Fig.7.1 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Vladivostok

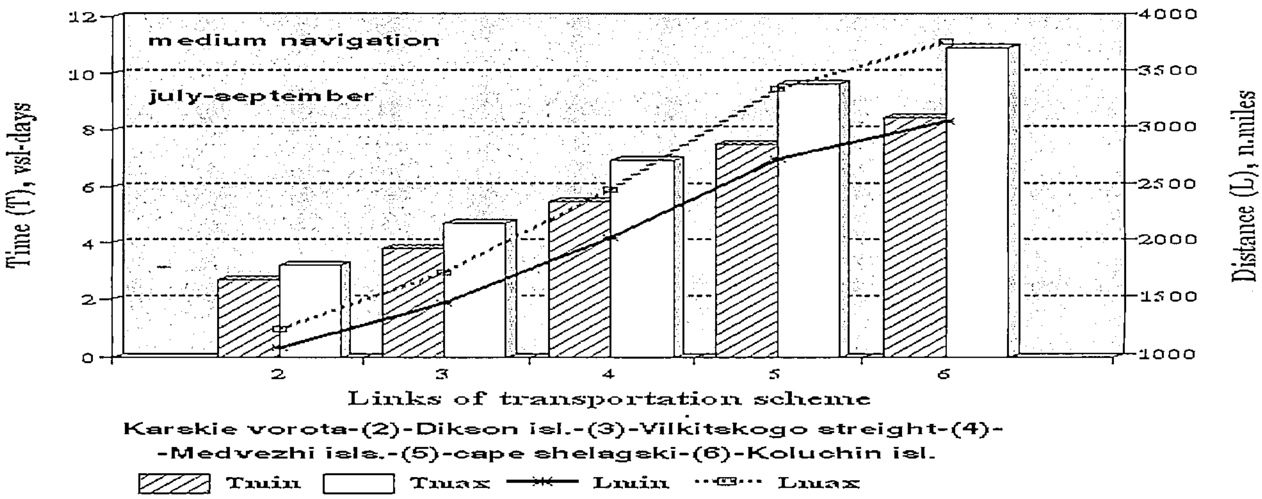


Fig.7.2 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Vladivostok

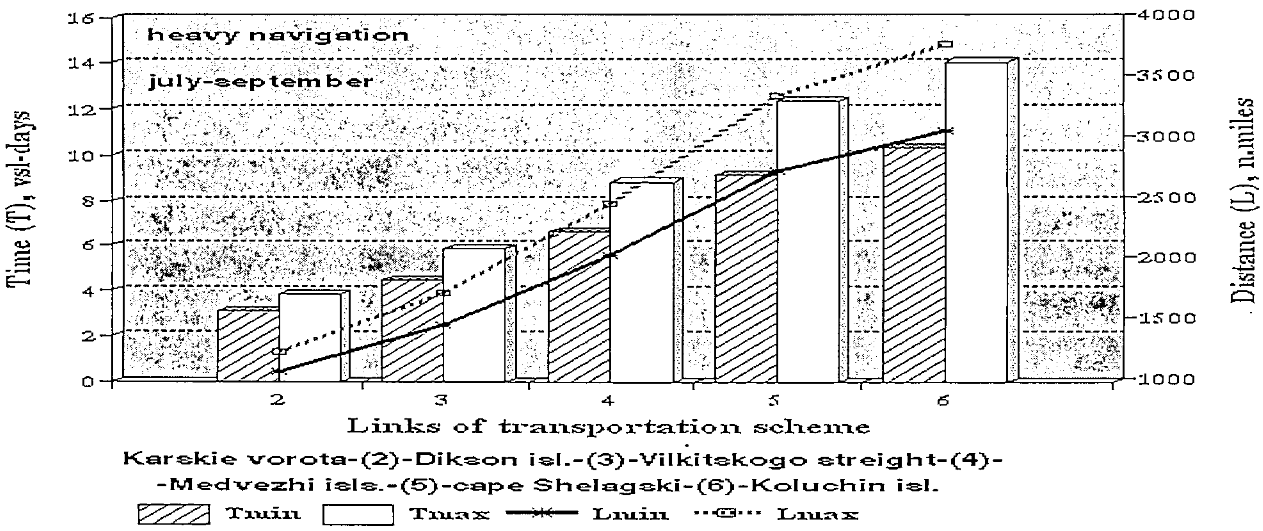


Fig.7.3 Trade model of ALV"Sevmorpyt" ice going on route Murmansk-Vladivostok

						TABLE	8		
TRADE MODEL FOR VESSEL TYPE					m/v"Norilsk"				
transport scheme				Murmansk-NSR-Vladivostok					
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	17	17	17	17	17	17	17		
Coefficient of speed in ice									
	1	0.88	0.88	0.88	0.88	0.88	1		
Coefficient of manoeuvring									
	1	1.05	1.05	1.05	1.05	1.05	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1087	1472	2045	2738	3069	5769		
Real speed, n.miles/vsl-day									
	408	359	359	359	359	359	408		
Time of proceeding the link, days									
6	1.4	1.44	1.07	1.6	1.93	0.92	6.62	6	
Time of voyage (integral), days									
6	7.4	8.84	9.91	11.5	13.4	14.4	21	27	
***								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	6	7	8	
***								************	
"Pessimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	17	17	17	17	17	17	17		
Coefficient of speed in ice									
	1	0.52	0.52	0.52	0.52	0.52	1		
Coefficient of manoeuvring									
	1	1.35	1.35	1.35	1.35	1.35	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1234	1730	2467	3358	3783	6483		
Real speed, n.miles/vsl-day									
	408	212	212	212	212	212	408		
Time of proceeding the link, days									
8	1.4	3.13	2.34	3.47	4.2	2	6.62	8	
Time of voyage (integral), days									
8	9.4	12.5	14.9	18.3	22.5	24.5	31.2	39.2	
Links of transport scheme & their numbers:									
0	-	on bearth at port of Murmansk							
1	-	p.Murmansk-Karskie vorota							
2	-	Karskie vorota-Dikson isl.							
3	-	Dikson isl.-Vilkitskogo streight							
4	-	Vilkitskogo streight-Medvezhi isls.							
5	-	Medvezhi isls.-cape Shelagski							
6	-	cape Shelagski-Koluchin isl.							
7	-	Koluchin isl.-cape Dezhneva-p.Vladivostok							
8	-	on bearth at port of Vladivostok							

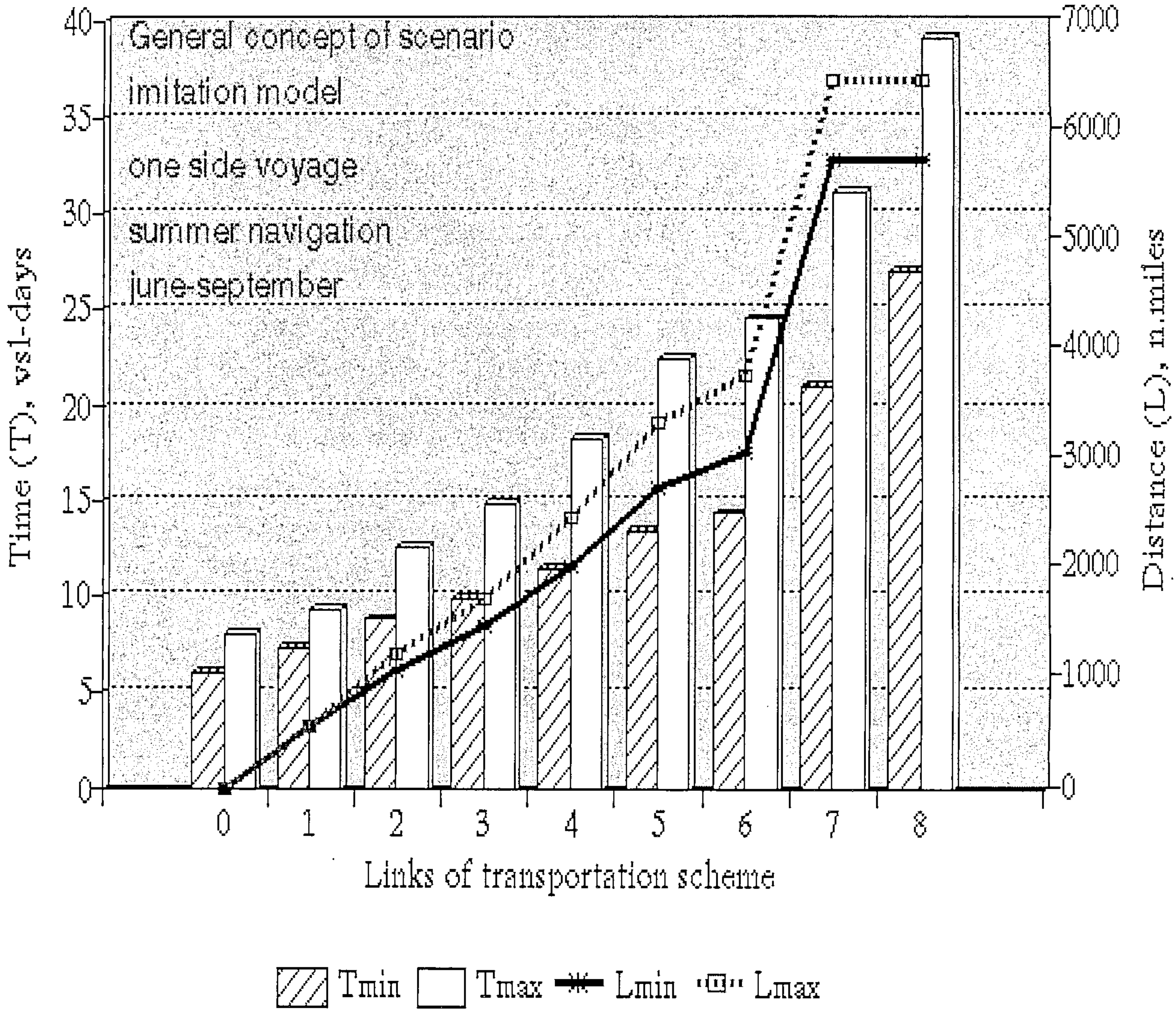


Fig.8 Trade model of m/v"Norilsk"
voyage Murmansk-NSR-Vladivostok.

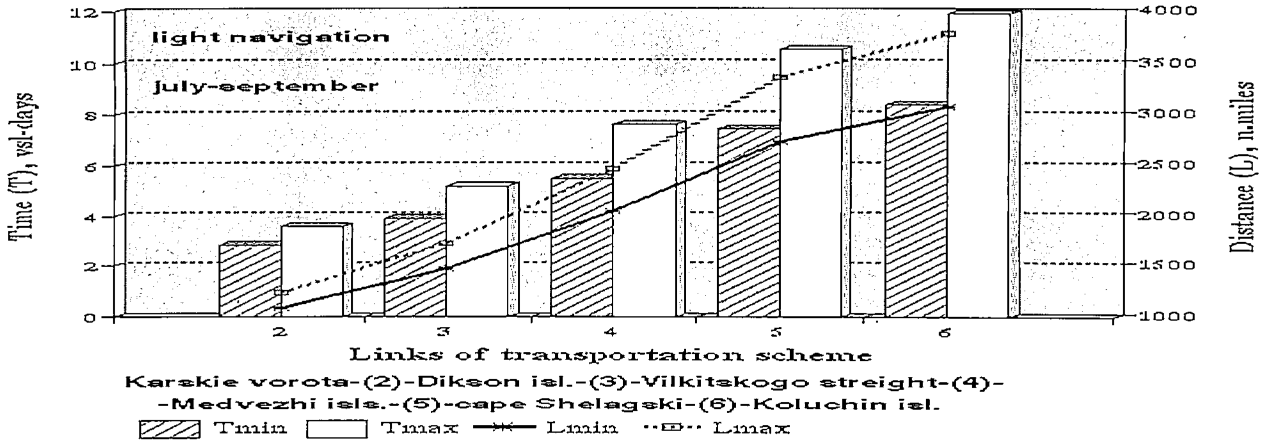


Fig.8.1 Trade model of m/v"Norilsk" ice going on route Murmansk-Vladivostok

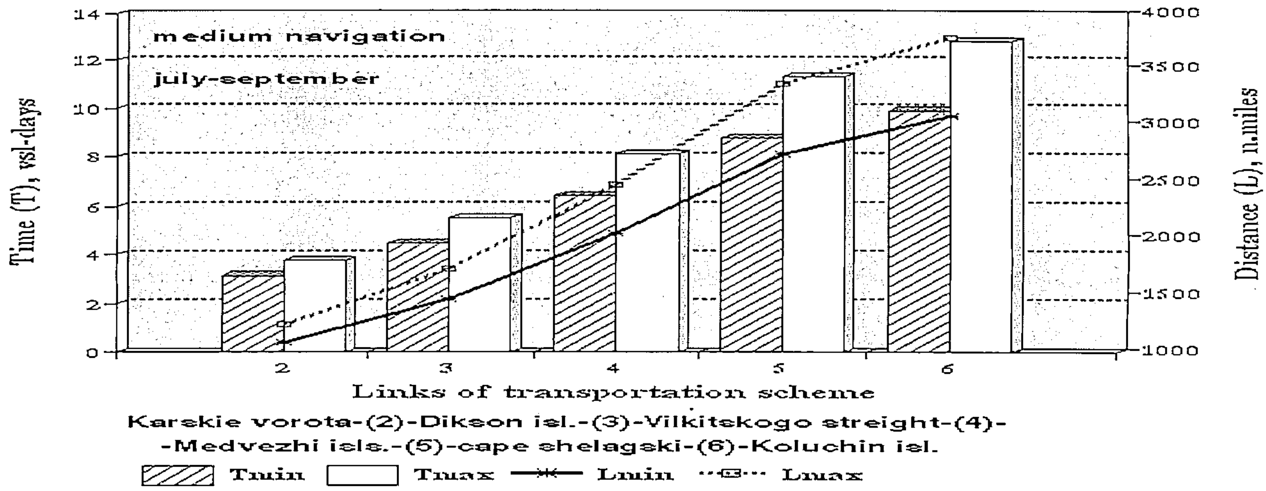


Fig.8.2 Trade model of m/v"Norilsk" ice going on route Murmansk-Vladivostok

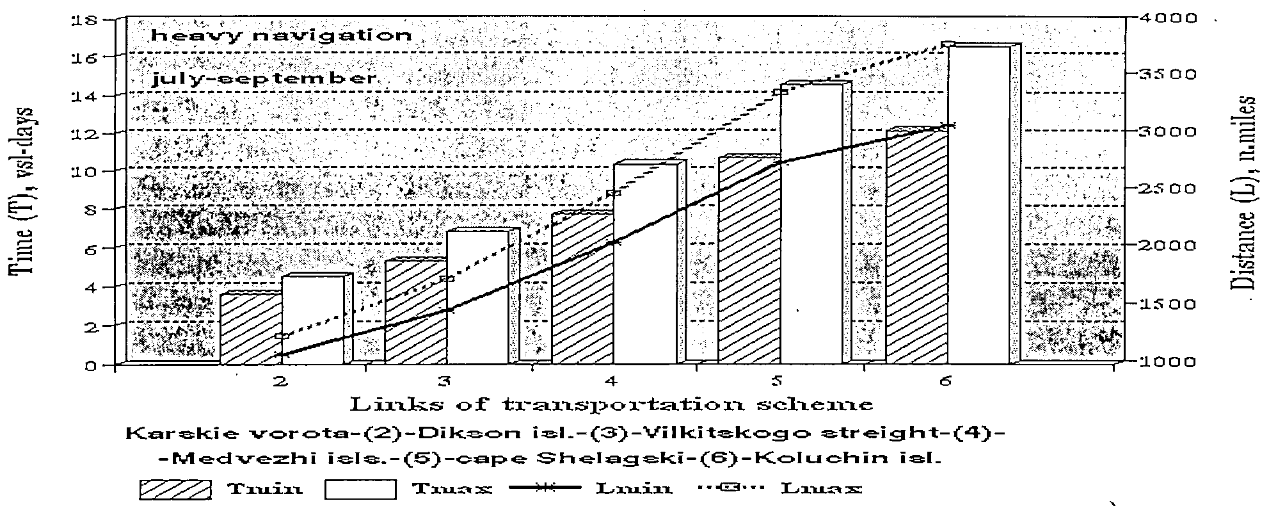


Fig.8.3 Trade model of m/v"Norilsk" ice going on route Murmansk-Vladivostok

						TABLE	9		
TRADE MODEL FOR VESSEL TYPE					m/v"Dm.Donskoi"				
transport scheme				Murmansk-NSR-Vladivostok					
"Optimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	15	15	15	15	15	15	15		
Coefficient of speed in ice									
	1	0.88	0.88	0.88	0.88	0.88	1		
Coefficient of manoeuvring									
	1	1.05	1.05	1.05	1.05	1.05	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1087	1472	2045	2738	3069	5769		
Real speed, n.miles/vsl-day									
	360	317	317	317	317	317	360		
Time of proceeding the link, days									
4	1.58	1.63	1.22	1.81	2.19	1.04	7.5	4	
Time of voyage (integral), days									
4	5.58	7.21	8.43	10.2	12.4	13.5	21	25	
**								************	
Links of transport scheme & their numbers:									
0	1	2	3	4	5	6	7	8	
**								************	
"Pessimistic" prognosis									
DATA BASE:									
Distance of link, n.miles									
	570	492	367	546	660	315	2700		
Service speed, knots									
	15	15	15	15	15	15	15		
Coefficient of speed in ice									
	1	0.52	0.52	0.52	0.52	0.52	1		
Coefficient of manoeuvring									
	1	1.35	1.35	1.35	1.35	1.35	1		
CALCULATION RESULTS:									
Real distance (integral), n.miles									
	570	1234	1730	2467	3358	3783	6483		
Real speed, n.miles/vsl-day									
	360	187	187	187	187	187	360		
Time of proceeding the link, days									
7	1.58	3.55	2.65	3.94	4.76	2.27	7.5	7	
Time of voyage (integral), days									
7	8.58	12.1	14.8	18.7	23.5	25.7	33.2	40.2	
Links of transport scheme & their numbers:									
0	-	on bearth at port of Murmansk							
1	-	p.Murmansk-Karskie vorota							
2	-	Karskie vorota-Dikson isl.							
3	-	Dikson isl.-Vilkitskogo streight							
4	-	Vilkitskogo streight-Medvezhi isls.							
5	-	Medvezhi isls.-cape Shelagski							
6	-	cape Shelagski-Koluchin isl.							
7	-	Koluchin isl.-cape Dezhneva-p.Vladivostok							
8	-	on bearth at port of Vladivostok							

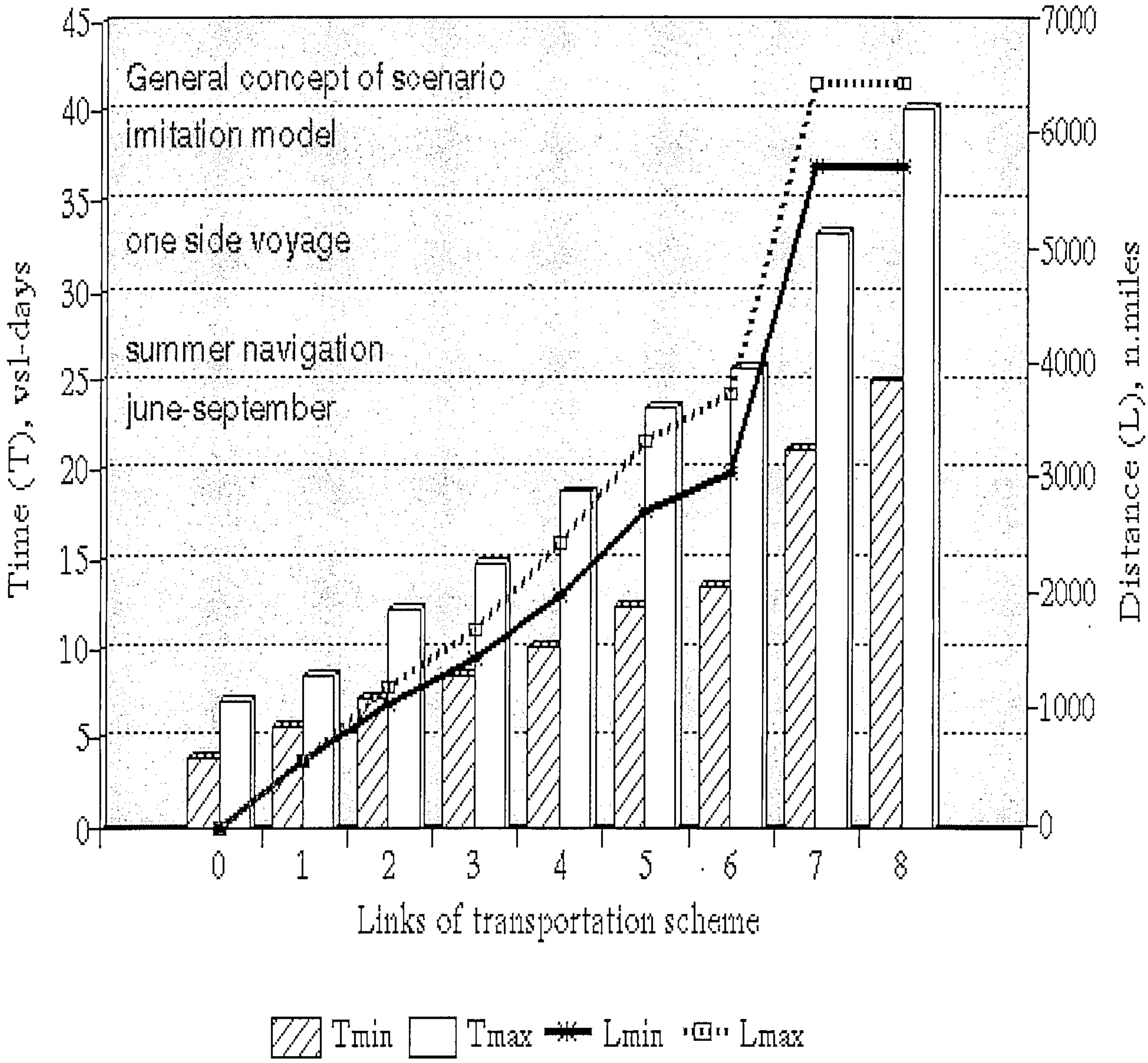


Fig.9 Trade model of m/v"Dm.Donskoy"
voyage Murmansk-NSR-Vladivostok.

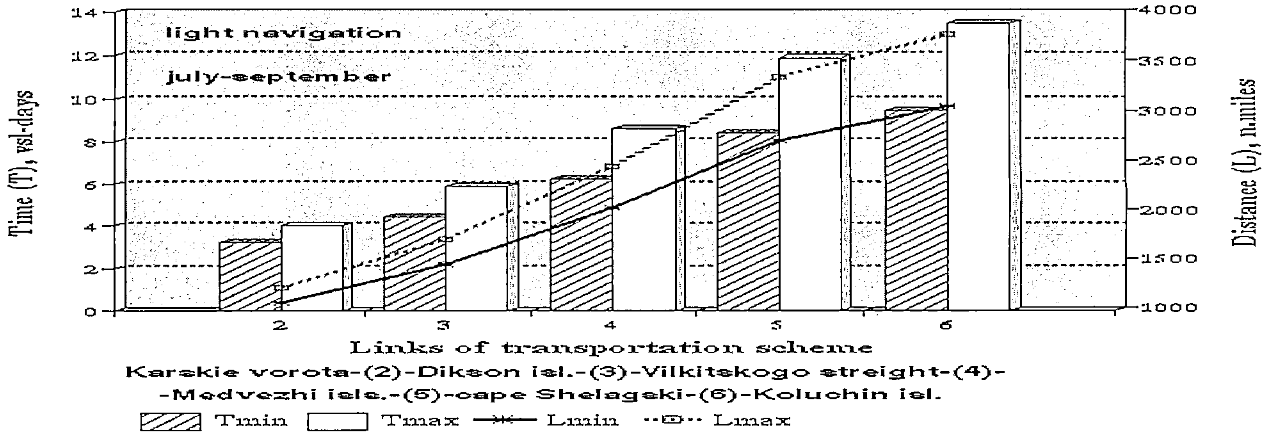


Fig.9.1 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Vladivostok

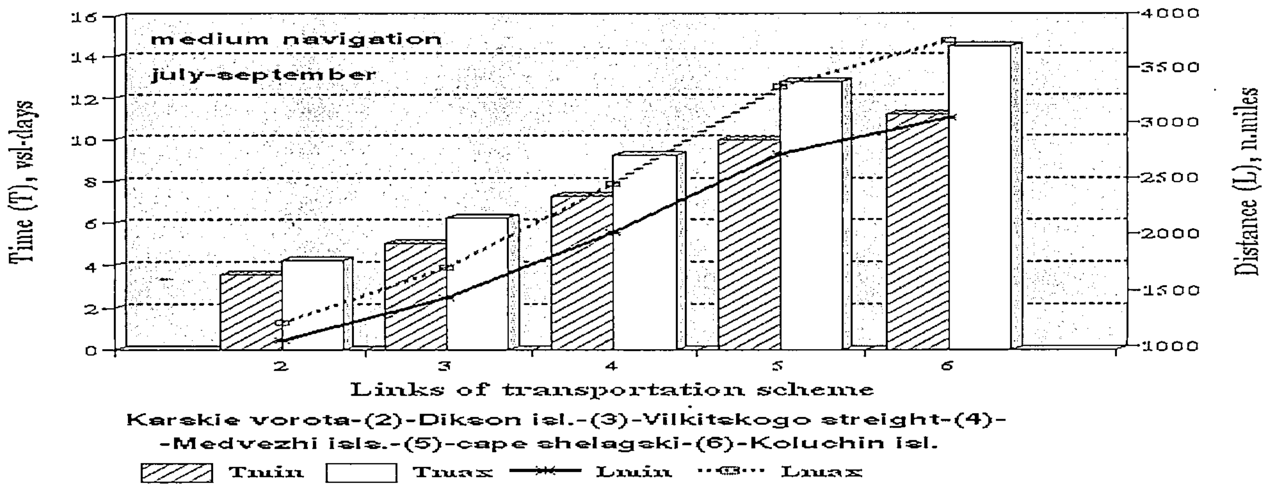


Fig.9.2 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Vladivostok

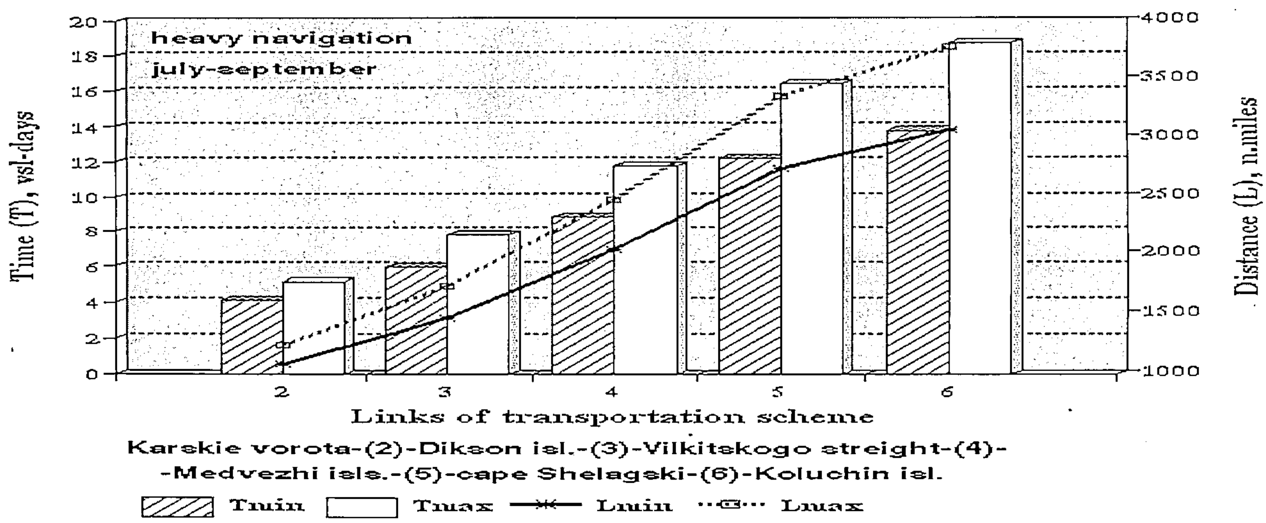


Fig.9.3 Trade model of m/v"Dm.Donskoy" ice going on route Murmansk-Vladivostok

Appendix 4

Assessment of Potential Operation Effectiveness of the Perspective Types of Vessels on Scenarios of Navigation

According to the scenario the assessment of potential effectiveness of the Arctic shipping is based on logical presumptions. At present creation of large-series construction of the ULA-class vessels is carried out on the existing ship -building basis. Expert data received by the Central Marine Research and Design Institute (CNIIMF) specialists in designing new types of vessels, who took into account calculated labour input and metal consumption, show that the cost of a bulker built in accordance with the requirements of UL-class may be 10-15% higher than of a bulker of equal deadweight but without ice-class. The rise in the cost is mainly explained by a higher cost of the vessel's hull. The estimated cost of an equal ULA-class bulker may rise by 30-40% owing to both a higher cost of the hull and much more powerful propulsion plant.

It would be also a logic assumption that higher costs of other types of vessels, if a comparison is made, will also be mainly explained by higher costs of their hulls and power plants.

This estimate, however, does not take into account market conditions which influence the actual contract prime cost of constructing vessels with non-standard technical parameters.

In order to give a correct estimate of potential reserves of economic effectiveness, the probable rise in construction cost of a UL-class bulker will be considered as exceeding that of a non-ice-class vessel of equal dead weight by 20%, and by 50% in case of an ULA-class vessel.

An analysis of the Lloyd's data regarding world average statistical costs of bulker construction during the period: last quarter of 1996 - first quarter 1997, and the trends in the costs for the last three years, makes possible to predict most probable perspective specific construction costs for the bulkers of 20,000 to 60,000 t dwt.

The predicted costs of the required specialised vessels are shown in Table A4.1.

Table A4.1

Predicted estimated costs of ice-class vessels

Type of vessel	Ice class	Deadweight, t	Construction cost, mill USD
SM-15A	ULA	19940	34
SKN-2600A	ULA	44920	63
SN-56A	ULA	56470	32

1. Determination of Most Probable Parameters of Working Expenses

Today's international experience in transport fleet operations in the Arctic is of irregular character. Deliveries of supplies in high latitude regions by sea in the conditions comparable with those of the Northern Sea Route are, as a rule, of no obvious commercial character.

Russia has gained a reach experience in the Arctic sea navigation. However, economical results of such transportation are of no pràctical use, as their parameters cannot be compared with modern international practices in commercial shipping.

As a matter of fact, at present, there are no systematised data which could be used for working out standard methods of determining operational and economic parameters for the utilisation of specialised transport fleet in ice conditions of the Arctic.

Therefore, to determine working expenses of the vessels to be used on the NSR routes, we will base our estimates on the assumption that current working expenses will, at least, be not lower than those calculated for analogous non-ice-class vessels.

The "Drewry Ltd."[1] predict daily operating costs for dry cargo vessels of 25,000-65,000 t dwt until the year of 2000 in the amount of 7,000-9,000 USD, i.e. 2.5-3.3 mill per annum.

[1] The source: Ship Costs in the 1990s: The Economics of Ship Operation and Ownership. - "Drewry Shipping Consultants Ltd.", London, 1994.

The following items have been included in the calculation of the predicted costs:

- Manning cost;
- Insurance cost;
- R & M;
- Stores and Supply;
- Administration.

The amount of the predicted constant daily proceeding expenses including operation costs and fuel costs when under way and in port, have been taken as a basis for approximate estimates and are shown in Table A4.2.

Table A4.2

Estimated working costs for the near future, thousand USD /ship-day.

Type of vessel	Fuel		Operation costs	Total	
	Under way	in port		under way	in port
SM-15A	9.9	0.5	7.6	17.5	8.2
SN-56A	10.8	0.4	10.0	20.8	10.4
SKN-2600A	34.1	1.5	10.0	44.1	11.5

Note: Annual period of operation is 330 ship-days/per annum

The predicted aggregate working costs include the estimated amounts of required average intensity of capital investments reproduction, imitating the expenditures of the own and borrowed capital; loan interest and the interest of the ship's operator and/or ship-owner which

have been corrected by the amount of the "interest" playing the part of the discounting factor within the period of ship's amortisation (15 years), residual cost not included.

2. Determination of Minimum Reasonable Cost of Delivery

Due to the results of calculations made by means of the above methods it has become possible to determine reasonable utilisation of the perspective types of vessels sailing in the Arctic.

2.1. Vessel of SM-15A type

Transport shipments:

One shipment - about 15,000 tons of group age general cargo.

Critical amount to find the upper limit of effective operation - about 10,000 tons.

Transport route: round voyage Murmansk - Dudinka - Murmansk, full load, both ways.

Estimated working expenses including operation costs, fuel and 3 variants of capital costs imitated by the average intensity of capital investments reproduction for the interest of 5, 10 and 15% per annum on the capital equal to the estimated cost of the vessel minus the amount of full and even amortisation during 15 years:

Interest	5	10	15	%
Under way	27.12	29.86	32.61	thousand USD/day
In port	17.82	20.56	23.31	-"-

The total time of a round voyage: the optimum variant - 32 ship/days of which total time in port - 24 ship/days (2 loading and 2 discharging operations).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	216.9	238.9	260.9	thousand USD
In port	427.6	493.5	559.5	-"-
Total	644.5	732.4	820.4	thousand USD

The figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 10,000 tons	32.23	36.62	41.02	USD/ton
Shipment of 15,000 tons	21.48	24.41	27.35	-"-

The minimum permissible transport tariff ensuring the ship owner/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 10,000 tons	35.10	43.16	52.00	USD/ton
Shipment of 15,000 tons	23.40	28.77	34.67	-"-

The worst (pessimistic) variant - 51.8 ship/days of which total time in port - 32 ship/days (two loading and two discharging operations.

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	536.9	591.3	645.7	thousand USD
In port	570.1	658.0	746.0	-"-
Total	1107.0	1249.0	1391.7	thousand USD

Where the figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 10,000 tons	55.35	62.47	69.58	USD/ton
Shipment of 15,000 tons	36.90	41.64	46.39	-"-

The minimum permissible estimated transport tariff ensuring the ship owner/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 10,000 tons	60.29	73.62	88.22	USD/ton
Shipment of 15,000 tons	40.20	49.08	58.81	-"-

Transport route: round voyage Vladivostok - Pevek - Vladivostok, full load, one way.
The total time of a round voyage: the optimum variant - 27.4 ship/days, of which total time in port - 12 ship/days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	417.6	459.9	502.2	thousand USD
In port	213.8	246.8	279.7	-"-
Total	631.4	706.7	781.9	thousand USD

The figures of the minimum estimated reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 10,000 tons	63.14	70.67	78.19	USD/ton
Shipment of 15,000 tons	42.09	47.11	52.13	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/ Operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value_tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 10,000 tons	68.78	83.29	99.14	USD/ton
Shipment of 15,000 tons	45.85	55.52	66.09	-"-

The worst (pessimistic) variant - 33.9 ship/days of which total time in port - 16 ship/ days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	485.4	534.6	583.7	thousand USD
In port	285.1	329.0	373.0	-"-
Total	770.5	863.6	956.7	thousand USD

Where the figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 10,000 tons	77.04	86.36	95.67	USD/ton
Shipment of 15,000 tons	51.36	57.57	63.78	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 10,000 tons	83.92	101.80	121.30	USD/ton
Shipment of 15,000 tons	55.95	67.85	80.87	-"-

2.2. Vessel of SN-56A type

Transport shipments:

- 100% of load-carrying capacity i.e. approximately 50,000 tons of mass bulk cargo;
- critical amount to find the upper limit of effective operation - 60% of load-carrying capacity of group age general cargo i.e. approximately 30,000 tons.

The above parameter takes into account impossibility of ensuring balanced cargo-flows in both directions for an average estimated round voyage.

Transport route: one-way voyage Murmansk - the NSR - Vladivostok.

Estimated working expenses including operation costs, fuel and three variants of capital costs, imitated by the estimated average intensity of capital investments reproductions for the interest of 5, 10 and 15% per annum on the capital equal to the estimated cost of the vessel minus the amount of full and even amortisation during 15 years:

Interest	5	10	15	%
Under way	29.85	32.44	35.02	thousand USD/day
In port	19.45	22.04	24.62	-"-

The total time of voyage: the optimum variant - 29.0 ship/days of which total time on port - 12 ship/days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	507.5	551.4	595.4	thousand USD
In port	233.4	264.4	295.5	-"-
Total	740.9	815.8	890.9	thousand USD

The figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 50,000 tons	14.82	16.32	17.82	USD/ton
Shipment of 30,000 tons	24.70	27.20	29.69	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 50,000 tons	16.14	19.23	22.59	USD/ton
Shipment of 30,000 tons	26.90	29.62	37.65	-"-

The worst (pessimistic) variant - 46.2 ship/days of which total time in port - 20 ship/ days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	782.1	849.8	917.6	thousand USD
In port	389.0	440.7	492.4	-"-
Total	1171.1	1290.5	1410.0	thousand USD

Where the figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 50,000 tons	23.42	25.81	28.20	USD/ton
Shipment of 30,000 tons	39.04	43.02	47.00	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 50,000 tons	21.51	30.42	35.75	USD/ton
Shipment of 30,000 tons	42.52	50.70	59.59	-"-

2.3. Vessel of SKN-2600A Type

Transport shipments:

- 100% of load-carrying capacity i.e. 2,600 TEU, which is the upper limit of the theoretical maximum of effective ship's operations;
- critical amount to find the extreme effectiveness of operation - 60% of load-carrying capacity i.e. 1,600 TEU.

The practices of world container-carrying trade during the last 10 years determined the reserves of the economic stability for a newly -designed container-carrier. The parameters of effectiveness of its operation must be positive when 60% of its load-carrying capacity have been used.

The above figure takes into account practical impossibility of ensuring balanced bulk cargo-flows in both directions for an average estimated round voyage.

Transport route: one-way voyage Murmansk - the NSR - Vladivostok.

The estimated working expenses including operation costs, fuel and three variants of capital costs, imitated by the estimated average intensity of capital investments reproductions for the interest of 5, 10 and 15% per annum on the capital equal to the estimated cost of the vessel minus the amount of full and even amortisation during 15 years:

Interest	5	10	15	%
Under way	61.92	67.01	72.10	thousand USD/day
In port	28.82	33.31	38.40	-"-

The total time of voyage: the optimum variant - 21.6 ship/days of which total time on port - 10 ship/days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	718.3	777.3	836.4	thousand USD
In port	282.2	333.1	384.0	-"-
Total	1000.5	1110.4	1220.4	thousand USD

The figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 2,600 TEU	376.10	417.40	458.80	USD/ton
Shipment of 1,600 TEU	625.30	694.00	762.70	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 2,600 tons	409.70	492.00	581.70	USD/TEU
Shipment of 1,600 TEU	681.10	817.90	967.00	-"-

The worst (pessimistic) variant - 36.5 ship/ days of which total time in port - 18 ship/days (one loading and one discharging operation).

The estimated aggregate ship's expenses during one voyage will be:

Interest	5	10	15	%
Under way	1145.0	1240.0	1334.0	thousand USD
In port	507.9	599.6	691.2	-"-
Total	1652.9	1839.6	2025.2	thousand USD

Where the figures of the estimated minimum reasonable rate of freight (RFR) in the amount of the delivery prime cost will be:

Interest	5	10	15	%
Shipment of 2,600 TEU	621.60	691.40	761.30	USD/TEU
Shipment of 1,600 TEU	1033.00	1150.00	1266.00	-"-

The minimum permissible estimated transport tariff ensuring the ship owner's/operator's profit on aggregate expenses in the amount of the interest on the capital with an allowance for 20% added value tax and 30% profit tax will be:

Interest	5	10	15	%
Shipment of 2,600 TEU	677.10	814.90	965.20	USD/TEU
Shipment of 1,600 TEU	1126.0	1355.0	1605.0	-"-

General conclusion: The figures of sea transportation prime costs (RFR) and minimum permissible tariffs calculated on the basis of the used method are comparable with the existing rates of freight for tramp transportation between estimated ports of the transport routes. Thus, it becomes possible to draw a preliminary conclusion about potential economic effectiveness of the regular operation of specialised Arctic vessels along estimated transport routes.

Appendix 5

Review by Claude Daley, Dr. Tech., P. Eng., Associate Professor Memorial University of Newfoundland St. John's, NF, Canada, A1B 3x5.

Paper: Scenarios of Seasonal and Year Round Navigation along the Northern Sea Route.

Comments

The paper describes various issues related to shipping transportation on the Northern Sea Route. The focus is on simple algorithms that can be used to estimate the times required to transport goods by sea. The costs per ton that follow from the times are discussed in an appendix.

The presentation is generally quite complete. The English grammar is weak in many places. Word usage is sometimes awkward and difficult to follow. For example, on page 9, "Scenario of navigation planning…" might be better phrased as "Description of the navigation planning process…".

The words: "scenario", "immersion", "terriplans" should be precisely defined.

The report gives the feeling of being largely anecdotal, rather than scientific.

The report is full of unsubstantiated phrases, such as (pg. 17) "Practical experience has proved…" with no reference, no data, not even an example of a particular case. The reader is left to believe or not, on faith.

The self – laudatory comments (e.g. pg. 7: "we have used the wide practical experience of the master-mariner and doctor Vasiliy Smirnov…") add to the sense of being anecdotal rather then scientific.

Pages 15 – 17 discuss and 'algorithm' : N = Vcy x T x n / 2S. This algorithm is obviously trivial. It suggests that convoys move at a speed that does not depend on the number of ships in the convoy.

Most of the paper deals with the presentation of simple 'rules of thumb' that allow the determination of typical effective speeds in various regions and times of year. This is useful practical information.

Comments on pg. 47 concerning opinions of appropriate vessel characteristics are unsubstantiated, other than as opinions based on certain experience. The discussion of "immersion" in shallow water is similarly anecdotal, although useful, information.

In general, references for the source of the coefficients presented should be given.

The report may be of much practical use for voyage planning, but is of limited scientific value in understanding the causes of winter shipping difficulties.

Appendix 6

Reply to the Reviewer by Authors of INSROP Report III.07.8. "Scenarios of Seasonal and Year Round Navigation along the Northern Sea Route"

We wish to express our appreciation to Mr. Claude Daley for all his efforts and deep insight into the problem discussed in our report.

As regards the English language, we have some lingering hope that it is improved in this version of the report. In this connection, some passages of the report have been changed and vague expressions have been substituted.

Certain explanations and clarifications with regard to usage of particular terms are given below.

"Scenario": Navigation Scenario is a description of the process of shipping along the NSR through such indices as speed and time of passage along rated stretches. The scenario deals with ships of particular sizes under conditions of light, medium and heavy navigation.

Speed and time of passage along rated stretches are determined by simulation of an especially generated information array for each ship or design composition of the convoy. System analysis technique is used to determine changes of successive positions of ships and icebreakers moving independently in convoy when passing along ice stretches under conditions of light, medium and heavy navigation. It is obvious that the matter requires amplification.

As for the terms "immersion" and "terriplans", they are not used in this version of the report.

****

There are some replies to Reviewer's particular remarks on the report.

Reviewer:

Pages 15 – 17 discuss and 'algorithm' : N = Vcy x T x n / 2S. This algorithm is obviously trivial. It suggests that convoys move at a speed that does not depend on the number of ships in the convoy.

In general, references for the source of the coefficients presented should be given.

Reply to the Reviewer:

Speeds of ships moving in convoy under icebreaker assistance in ice conditions are established by the leader and based on the speed of the most slow-running ship in the group.

This rule is determined by the ice navigation tactics and documents regulating the safety of navigation along the NSR.

The table speeds given in the report shows ship speeds corresponding to types of ships under consideration. The data have been taken from the records concerning fleet operation of the Murmansk Shipping Company by navigational seasons and ice conditions from 1989 to 1993.

The System of speed coefficients suggested in the work is a result of processing actual observation materials, made by the mathematical statistics techniques.

The design ratios given with 95 % probability are in excellent agreement with the actual data on movement of ships and convoys under various ice conditions during the Arctic navigation periods.

The speed characteristics and ice transiting performance of the nuclear barge-carrier "Sevmorput" were obtained during the work performed by a group of ship designers and CNIIMF's specialists on board the barge-carrier in October-November 1989 and during operation of the ship on the NSR seaways and in the Yenisey River from 1989 to 1993.

To clarify changes of ship's draft in shallow water under ice conditions, a series of field observations was made by Captain V. Smirnov during the period from 1985 to 1992. The methods applied by Captain V. Smirnov were agreed with the Maritime Service of the Murmansk Shipping Company and CNIIMF branch office in Murmansk.

The observations were made on shallow water stretches of the NSR seaways: Sannikov strait, Buor Haya Bay, Yenisey River (river bar, Turushinsky rift, Bolshoy Island).

Data were processed and coefficients calculated by means of mathematical statistics techniques, with the following works being used:

Dlin A.M. "Mathematical statistics in Engineering", Published by Sovetskaya Nauka, Moscow. 1959.

Kondrashikhin V.T. "Error Theory", Published by "Transport", Moskow.1969.

Pustylnik E.N. "Statistical methods of observation analysis and processing", Published by "Nauka",1968.

Reviewer:

The report is full of unsubstantiated phrases, such as (pg. 17) "Practical experience has proved..." with no reference, no data, not even an example of a particular case. The reader is left to believe or not, on faith.

Reply to the Reviewer:

All relevant sections 3-7, Appendix 3 are based on specific examples and a great body of measurements made for the basic types of Arctic ships. All these examples and results can be used to establish sailing tasks for each particular ship.

Reviewer:

Comments on pg. 47 concerning opinions of appropriate vessel characteristics are unsubstantiated, other than as opinions based on certain experience.

Reply to the Reviewer:

The reasons for selection of the acceptable characteristics of ice ships are grounded on the long-term experience of navigation along the NSR. First of all the requirements of the Russian register of Shipping are taken into consideration. The Register concentrates and generalizes this experience. Technical and operation characteristics of perspective types of vessels given in Appendix 1 (Table À1.3) take account of the above experience and requirements.

Reviewer:

The report may be of much practical use fore voyage planning, but is of limited scientific value in understanding the causes of winter shipping difficulties.

Reply to the Reviewer:

The result of this work has made it possible to find a way of systematizing statistical information regarding sailing of ships along the Northern Sea Route.

The reason for and difficulties of winter navigation are understood through quantitative estimation of voyage scenarios and scientifically substantiated selection of shipping routes for specific types of ships.

Organization of an information processing system to be used in scientific centers specially set up for this purpose (e.g. in Russia, Germany, Norway, Japan or other northern countries) will make it possible, in our opinion:

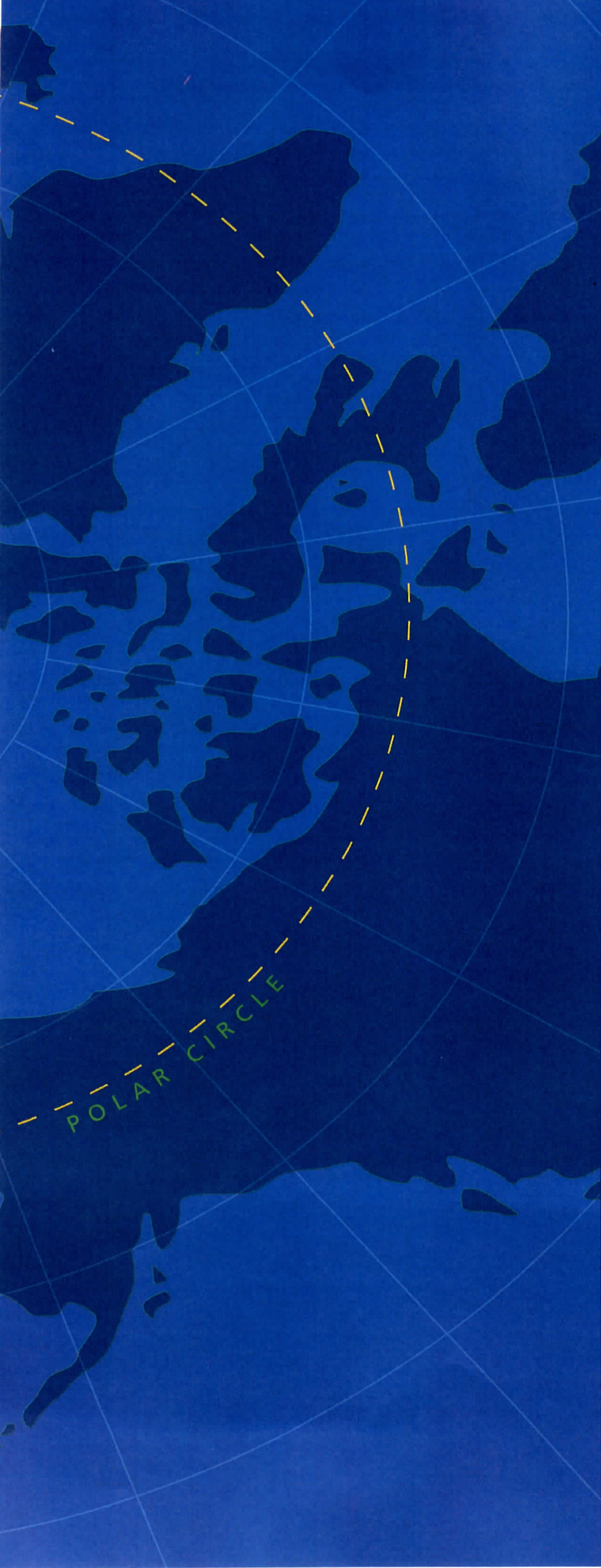
- to plan sailing tasks with a high degree of certainty;
- to organize fleet operation according to timetable;
- to substantiate the necessary transport expenses;
- to substantiate insurance rates for traffic along the NSR.

We believe that all these factors contribute to the scientific value of the report in view of the future development of the NSR.

The INSROP report III.07.8 includes all the replies to the Reviewer's comments. Editorial corrections and the English translation have been verified.

Best regards,

Y. Ivanov, N. Isakov



The three main cooperating institutions of INSROP

Ship & Ocean Foundation (SOF), Tokyo, Japan.
SOF was established in 1975 as a non-profit organization to advance modernization and rationalization of Japan's shipbuilding and related industries, and to give assistance to non-profit organizations associated with these industries. SOF is provided with operation funds by the Nippon Foundation, the world's largest foundation operated with revenue from motorboat racing. An integral part of SOF, the Tsukuba Institute, carries out experimental research into ocean environment protection and ocean development.

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.
CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stockholding company.

The Fridtjof Nansen Institute (FNI), Lysaker, Norway.
FNI was founded in 1958 and is based at Polhøgda, the home of Fridtjof Nansen, famous Norwegian polar explorer, scientist, humanist and statesman. The institute spesializes in applied social science research, with special focus on international resource and environmental management. In addition to INSROP, the research is organized in six integrated programmes. Typical of FNI research is a multidisciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.