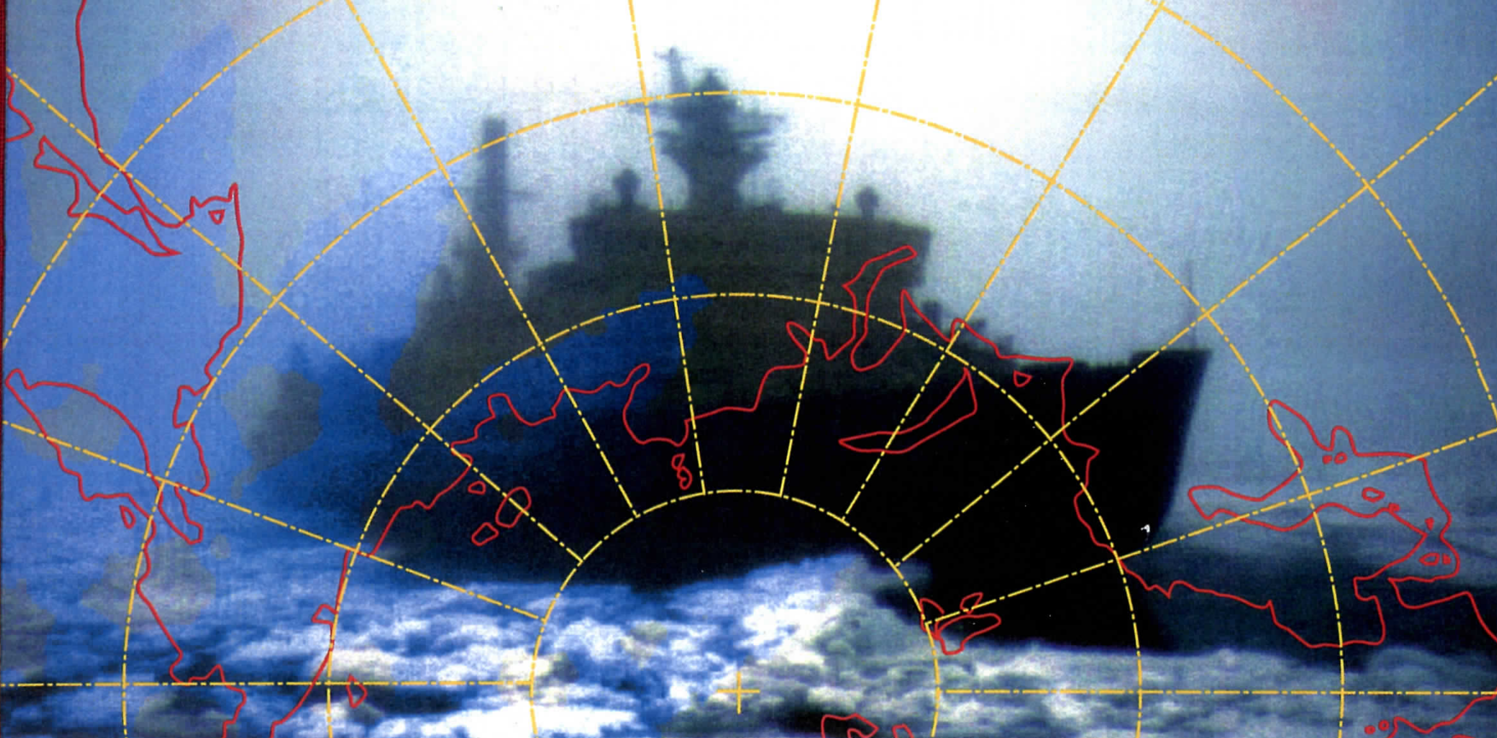

INSROP WORKING PAPER
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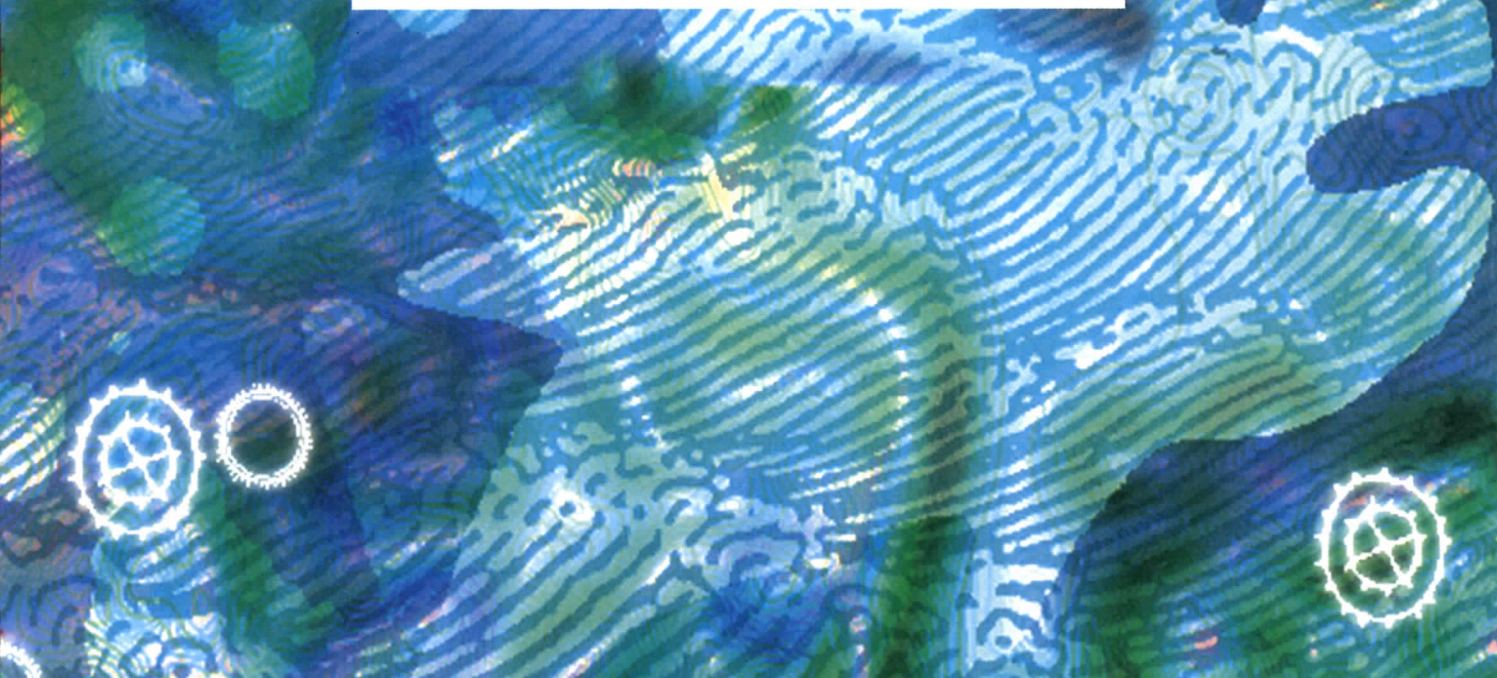
Survey of Logistics Models
Part 2: The Methodology of Simulative Modelling of Transport and Ice Breaker Fleets Operations in the Arctic

Anatoly Schelkanov and Yury Kelberg



INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

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Ship and Ocean Foundation, Japan

International Northern Sea Route Programme (INSROP)

Central Marine Research & Design Institute, Russia

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Part 2. The Methodology of Simulative Modelling of Transport and Ice Breaker Fleets Operation in the Arctic.

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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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Contents

1. Introduction

The review of logistic modelling carried out at the previous stage and the discussion of results with the supervisor indicated that the Russian side have to elaborate a methodology of simulative modelling and appropriate requirements for using a computer with reference to the functioning of transport and ice-breaker fleets in the Arctic in consideration of INSROP's needs and the available experience.

This necessity arises from the complexity of interactions of different types of vessels, ice-breakers and ports under various natural conditions the Arctic area that determines possible high risks when administrative, organizational matters and problems of investment concerning transportations in the Arctic are being solved.

Like the report [1] the following principles have been used to elaborate the methodology of simulative modelling of functioning of transport and ice-breaker fleets in the Arctic for INSROP:

- The aim of this computer modelling is accumulation, processing and output of economic and operational indices concerning the whole system and/or separate objects under given definite version of technical supply and transportation process.
- Certain vessels and ice-breakers which a user is interested in considering writing off, renovation, planned repairs, lease or time-charter and berths as well could serve as separate objects of the simulative model.
- Vessels might be received from outside as input flows of definite structure to be ice-breaker supported and handled, in order to render the model more adequate.
- The aim of modelling of port operation is to reveal the influence of the handling dynamics on indices of fleet operation.
- To evaluate accuracy of the results, computer visualization of the transportation process could include analysis of casual factors influence on duration of some operations (code time in the ice, loading, discharging etc).
- Vessel traffic-control and regulation of ice-breaker escort and port operation are carried out through modelling algorithm starting from appointed version of transportations & vessels allocation.

2. The simulative model of fleet operation.

The region for running vessels and ice-breakers in simulative model is determined by total combination of points (ports) and areas of a port and ice-breakers' supplies. "A point" means a dot marked on a map of water routes. A water route between two points indicates "an area". A point where cargo-vessels are handled is "a port". There might be some places for vessels' port supply (support) in the some port. Ice-breaker escort is used on areas of convoy sailing.

The number of areas where ice-breaker escort is used is inaccordance with adopted organization system of such escort in the Arctic.

The object of modelling in simulative model in time interval [T1, T2] is certain vessels, ports and ice-breakers. They are put into the examined transportation process by way of setting the date of their initial conditions.

The modelling process consists in consecutive conversion of system from one state to another including all arising interactions between objects to accumulate essential information to report.

The modelling algorithm controls this process in simulative model.

Simulation of vessel operation

Simulative process of vessel operation consists in consecutive trips prescribed to every vessel after input into the system and the removal of some vessels out of operation (if necessary). The trips in simulative model are the combination of transportation process stages such as loading, sailing, ice-breaker support, discharge.

Duration of loading-discharge in the model (including possible period of waiting) is determined by simulation of port operation.

"Sailing" characterizes the autonomous run of a vessel along certain passage of water route. Duration of this, stage in the model is determined in consideration of casual factors' influence.

Duration of ice-breaker support is determined by simulation of operation of ice-breakers.

The allotment of trips for vessels which are put into the system is fulfilled through realization of prescribed probabilities in the model. These probabilities are determined depending on type of vessel, previous trip and a month.

In addition to vessels attached to the system operation of vessels from outside to fulfil one certain trip for every vessel may be introduced into the system to provide adequacy of the model. In this case their introduction into the system is under control of intervals between arrivals of vessels with specified law of probability distribution.

Simulation of vessel handling in port

Simulative process of vessel handling in a port is carried out in cargo-places where standards of simultaneous handling (servicing) of vessels are determined. A vessel upon arrival (or under waiting) is put in handling if simultaneous handling is within limits of standard after berthing and she is the first in turn.

The time of berth occupation is determined by characteristics of current stage of trip and value of random quantity which characterizes and influences casual factors on handling of vessels.

Simulation of operation of ice-breakers

Like modelling of vessel operation simulative process of operation of ice-breaker fleet consists of: realization of accepted allocation of every ice-breaker (starting from its initial state) according to areas of ice-breaker support; removal of some of them from operation (repairs, lease etc.).

The following positions of ice-breakers in areas of ice-breaker support are possible:
ice-breaker escort of convoy;

- period of waiting for vessel arrival;
- autonomous sailing of ice-breaker in a certain area to provide vessel support.

Duration of convoy running along a certain passage depends on number of vessels in a convoy, minimal ice-class of vessel in a convoy, type of ice-breaker, area of escort and a month considering on influence of casual factors.

It is ruled in the model that there is a limit to the number of vessels in a convoy that is determined as prescribed maximum index (M).

A convoy is composed of vessels according to order of priorities of their arrivals for ice-breaker support. A convoy is considered to be completely formed if it consists of $m < M$ vessels and the period before arrival of a vessel $m + 1$ exceeds prescribed admissible period of waiting considering influence of casual factors.

An ice-breaker sails autonomously only in the case of earlier departure of regular caravan.

3. Description of modelling algorithm

Modelling algorithm carries out computer simulation of sailing, handling and ice-breaker support of vessels with accumulation of results of modelling.

An approach taken as a basis of the methodology for construction of modelling algorithm is in transformations of the state of system examined at discrete moments of simulation period (Table 1).

These transformations take place when the following events begin:

"A vessel has been put in operation or a vessel has finished her trip" (event 1).

"A vessel has arrived in port for handling" (event 2).

"Handling of vessel in port has finished" (event 3).

"A vessel has arrived at place of departure for ice-breaker support" (event 4).

"A vessel has arrived at destination under ice-breaker escort" (event 5).

"An ice-breaker has been put in operation or has arrived at destination to provide support for vessels" (event 6).

"A vessel has been received from outside to fulfil a trip" (event 7).

"A vessel must be removed from operation" (event 8).

"An ice-breaker must be removed from operation" (event 9).

For purposes of calculating indices of efficiency of operation of vessels and ice-breaker transformations of state of the system during the period [T1, T2] are carried out by using input data (parameters of the system) printed in Table 2 with accumulation of essential record information (Table 3). Indices of efficiency are averaged for the unit of several realizations to increase accuracy of results of modelling when influence of casual factors on transportation process is taken into consideration.

Table 1.

Variables which characterize the state of the system being modelled

Denomination of data	Designation of fields in record
1. Vessels ready for trips - M [1]	S* - vessel R* - finished trip t - time of trip ending
2. Vessels awaiting handling - M [2]	P* - point U* - area S* - vessel t - time of arrival
3. Vessels being handled - M [3]	P* - point U* - area S* - vessel t - time of handling expiry
4. Vessels under waiting of ice-breaker support - M [4]	P1* - point of departure P2* - point of destination S* - vessel t - time of arrival at point of departure
5. Vessel under ice-breaker escort - M [5]	P1* - point of departure P2* - point of destination S* - vessel t - time of escort expiry
6. Ice-breakers under waiting for vessels and during sailing - M [6]	P1* - point of departure P2* - point of destination L* - ice-breaker m - number of vessels in a convoy (m >= 0) t - time of arrival at point of destination
7. Vessels form input flows - M [7]	S* - vessel R - trip t - time of trip beginning
8. Characteristics of recent trips - M [8]	S* - vessel R - trip i - recent stage of trip

9. Data on removal of vessel's from operation - M [9]	S* - vessel t - time of removal from operation
10. Data on removal of ice-breakers from operation - M [10]	L* - ice-breaker t - time of removal from operation

1/ * means key field in record

Table 2.

Input data (parameters) of the system being modelled

Denomination of data	Designation of field in record
1. Vessels characteristics - P [1]	S* - vessel St - type of vessel
2. Characteristics of ice-breakers - P [2]	L* - ice-breaker Lt - type of ice-breaker
3. Characteristics of ports - P [3]	P* - point U* - area n - standard of simultaneous handling of vessels
4. Characteristics of areas where ice-breaker support is used - P [4]	P1*- point of departure P2*- point of destination (P1<P2) M - maximum number of vessels in a convoy To - average period of waiting for arrival of vessels to compose a convoy.
5. Characteristic of vessels from outside (input flows) - P [5]	K* - type of vessel R* - trip Tu - average interval of vessel arrivals
6. Characteristics of vessel types - P [6]	K* - type of vessel Lk - ice - class of vessel
7. Characterization of vessel allocation for transportation - P [7]	K* - type of vessel RO* - previous trip R* - prescribed trip Mt* - month v - probability of trip Tx - average duration of sailing at the first stage of trip R

8. Characteristics of trips - P [8]

K* - type of vessel
R* - trip
I* - stage number
a - type of stage (handling, ice-breaker support, sailing)
b - point (of handling, of beginning of ice-breaker support, of sailing)
c - sector of port or point of ice-breaker support expiry
T - average duration of handling, sailing or autonomous sailing of ice-breakers

9. Standards of ice-breaker sailing and ice-breaker support - P [9]

P1*- point of departure
P2* - point of destination (P1 < P2)
Lt* - type of ice-breaker
m* - number of vessels in a convoy (m >= 0)
Lk* - minimal ice-class of vessel in a convoy
Mt* - month
TL - average duration of ice-breaker support of a convoy or autonomous sailing of ice-breaker

10. Parameters of random quantities - P[10]

N* - random quantity number that characterizes relative deviation from average duration of:
- ice-breaker support (N = 1);
- vessel running (N = 2);
- handling of vessels (N = 3);
- admissible period of waiting of ice-breaker for arrival of vessel to compose a convoy (N = 4);
- intervals of vessel arrivals (N= 5);

w[j] - left limit value of j - interval in the area of random quantity values; the probability of interval 1/ choice is 1/z (j= 0,1,...,z)

11. Time budget for vessel - P [11]	S* - vessel t1* - time of putting in operation t2 - time of removal from operation R - prescribed trip
12.Time budget for ice-breakers - P [12]	L* - ice-breaker t1* - time of putting in operation t2 - time of removal from operation P1 - point of departure P2 - point of destination (putting into operation)

1/ It is supposed that all random quantities of simulative model are given as piecewise linear approximation of accepted differential distribution function with expected value which equals one [2].

Table 3.

Data on operation of vessels and ice-breakers

Denomination of data	Designation of field in record
1. Data on operation of vessels - D [1]	S* - vessel R* - trip I* - stage t1 - time of arrival t2 - time of stage beginning
2. Data on operation of ice-breakers - D [2]	L* - ice-breaker P1*- point of departure P2*- point of destination t1 - time of arrival in point of departure t2 - time of escort beginning or autonomous sailing m - number of vessels in a convoy

The general scheme of algorithm might be reported as a sequence of the following stages of computing process:

Stage 1. Giving variables their initial quantities that characterizes current state of the system being modelled including model time t which is zero.

Stage 2. Choosing of event with minimal time of beginning to>t.

Stage 3. Processing of selected event with accumulation of essential record information about operation of vessels and ice-breaker.

Stage 4. Choosing of unprocessed event with time of beginning t = to. In the case of existence of such event transition to stage 3 is carried out.

Stage 5. Transition to model time t = to. If the time of expiry of modelling T2 > t transition to stage 2 is carried out.

Stage 6. Calculation and accumulation indices of the efficiency of the system functioning. If it is necessary to fulfil additional realization of modelling process transition to stage 1 is carried out.

Stage 7. Output of results of modelling.

Realization of stage 1 is carried out by using input data on time budget of vessels and ice-breakers (parameters from P [11] and P [12], table 2). For this purpose all records and indication which characterize the state of the system are excluded from M [1] - M [10] and D [1], D [2].

The records with minimal time of putting vessels in operation t1 (t1o) prescribed in P [11] and P [12] are included in M [1] and M [6] correspondingly for every vessel and ice- breaker. At the same time in M [6] the two following records are composed for every ice-breakers:

{P1, P2, L, m=0, t1o},

{P2, P1, L, m=0, t1o + TL* w1}, (1)

where TL - average period of autonomous sailing of ice-breaker

(from P [9] when m=0);

w1 - selected random quantity (according to data P [10]

when N = 1).

On the basis of the same data the records which characterize removal of vessels and ice-breakers from operation are composed in M [9] and M [10].

If the parameters P [5] are determined, the records which characterize the arrival of first vessels are composed in M [7] for every input flow

{K+N, R, T1+ Tu * w5}, (2)

where K+N - operation on monosemantic formation of vessel code;
K - type of vessel (selected from P [5]);
N - ordinal number of arrived vessels of K - type;
Tu - average interval between vessel arrivals (selected from P[5]);
w5 - selected random quantity (determined according to P[10] when N = 5).

The final information of stages 2 and 4 is Zo = 1, 2, 3, 4, 5, 6, 7, 9, 10 and the record from M [Zo] which characterizes the event begun.

Algorithms for processing of events at stage 3 might be reported as follows.

Algorithm for processing event 1

This algorithm is realized when Zo = 1 for the vessel So from M [1] by the following steps:

1) Choosing of trip Ro according to input data P [7] by realization of prescribed probabilities with using of random quantity which is uniformly distributed at the interval (0,1).

2) Determination of time of vessel arrival to fulfil the first stage of a trip - t [1]:

t [1] = to + Tx [j] * w2, (3)

where w2 - selected random quantity (according to data P [10] when N = 2).

3) Exclusion from the record on the vessel So from M [1]. Putting the record {So, Ro, O, to, t [1]} in D [1] and address to algorithm of autonomous modelling of the trip Ro with input data i = 1, t [1].
Output.

Algorithm of autonomous modelling of vessel trip

The following data are input information for this algorithm for the vessel So and the trip Ro:
stage number of transportation process which must be fulfilled - i;
time of vessel arrival to fulfil the stage i - t [i];
parameters of stages from P [8] - a [i], b [i], c [i] and T [i].

Algorithm consists of the following steps:

1) Testing whether the stage i exists. If not, transition to step 6 is carried out.
2) Testing whether the stage i is autonomous, i.e. c [i] = 0. In the case of positive result, transition to step 5 is carried out.
3) If a [i] determines ice-breaker support the record {b [i], c[i], So, t [i]} is composed in M [4].
   Then - transition to step 8.
4) If a [i] determines handling of a vessel in a port the record {b [i], c [i], So, t [i]} is composed in M [2].
   Then - transition to step 8.
5) Formation of time of stage expiry i by the following expression:

$$T [i+1] = t [i] + T [i] * wX, \quad (4)$$

   where wX - selected random quantity (determined according to P [10] when X = 2 in case of sailing, or X = 3 in case of handling).
   Inclusion the record {So, Ro, i, t [i], t [i]} in D [1].
   Giving i the value i+1 and transition to step 1.
6) Exclusion from the record on the vessel So from M [8]. If the vessel So has been received from outside - output.
7) Formation of the record {So, Ro, t [i]} in M [1].
   Output.
8) Formation of the record {So, Ro, i} in M [8].
   Output.

Algorithm for processing event 2

Event 2 characterizes an arrival of a vessel in a port at the time to tote handled and begins when Zo=2. Algorithm consists of the following steps:

1) If number of vessels being handled in a port Po, Uo according to data M [3] and P [3] is less then fixed for this port quota of simultaneous handling, the record {Po, Uo, So, to} is excluded from M [2].
   The record {Po, Uo, So, to + T [io] * w3} (5)
   is included in M [3],

where T [io] - average duration of handling (selected from P [8] according to data from P [6] and M [8]);
w3 - selected random quantity (determined according to P[10] when N = 3).
   The record {So, Ro, io, to, to} is included in D [1].
   Output.
2) The record {Po, Uo, So, to} is marked as processed record and then - output.

Algorithm for processing event 3

Event 3 characterizes the expiry of handling of the vessel So in the port at the time to and begins when Zo=3.

Algorithm consists of the following steps:

1) Realization of algorithm of autonomous modelling of the trip Ro for the vessel So (input data i+1 from M [8], to and data from P [8]).
2) If according to data M [2] there are vessels in the port Po,Uo waiting for handling, the record on the vessel Sm with minimal time of arrival in the port - tm is excluded from M [2].
   In M [3] the record on the vessel Sm is composed in accordance with the expression (5) when io = im.
   In D [1] the record {Sm, Rm, im, tm, to} is included.
3) Output.

Algorithm for processing event 4

Event 4 characterizes an arrival of a vessel at the time to for further ice-breaker support and begins when Zo=4.

Algorithm consists of the following steps:

1) If an ice-breaker is absent in the point P1o at the time to,
   i.e. there are no records with keys {P2o, P1o} in M [6] and t<=to, processed event is

marked and then - output.

2) If number of vessels waited for ice-breaker support that is determined in accordance to number of records in M [4] with keys {P1o, P2o} and t<=to, is more then or equal maximum number of vessels in a convoy (M) from P [4] or there is no record with keys {P1o, P2o} in M [4] and to<t<=to +To * w4,

where To - average time of ice-breaker waiting for vessel arrivals to compose the convoy (determined by P [4];

w4 - selected random quantity (determined according to P [10] when N = 4),

then the convoy leaves. The convoy consists of m<=M vessels S [j] from M [4] in order of priority of their arrivals in the port P1o.

For this purpose the following transformations are fulfilled:

a) Records {P1o, P2o, S [j], t [j], j = 1, 2, ..., m} are excluded from M [4].

b) Records {P1o, P2o, S [j], to + TL * w1, j = 1, 2, ... m} (6)
are included in M [5],

where TL - average time (period) of ice-breaker escort of a convoy selected from P [9] with using data from P [2] and P [6].

c) Records

{S [j], Ro, io, t [j], to} (7)

are included in D [1] concerning vessels S [j], j = 1, 2, ... m.

d) In D [2] concerning the ice-breaker Lo from M [6] which is characterized by the record with keys {P2o, P1o} and maximum time of arrival into the point P1o t<=to the following records are composed: {Lo, P1o, P2o, t, to, m} and
{Lo, P2o, P1o, t1, t1, 0}, (8)
if m=o for Lo in M [6] (t1=t in the record from M [6] with keys {P1o, P2o, Lo}).

e) In M [6] records on the ice-breaker Lo transform to
{P1o, P2o, Lo, m, to + TL * w1} - transition in P2o, (9)
{P2o, P1o, Lo, 0, t2 + TL * w1}, t2 = to + TL * w1
- return to P1o without vessels.
Output.

3) Marking processed events and output.

Algorithm for processing event 5

Event 5 characterizes the expiry of escort of a convoy at the time to and begins when Zo=5. Algorithm consists of the following steps:

1) Records on every vessel of a convoy S [j] with keys {P1o, P2o} and time of escort expiry to are excluded from M [5].
2) According to data from M [8], P [8] and to for S [j] autonomous modelling of a trip for every vessel is carried out.
3) Output.

Algorithm for processing event 6

Event 6 characterizes expiry of escort of a caravan or expiry of autonomous sailing of the ice-breaker Lo from the point P1o to the point P2o at the time to and begins when Zo=6.

Algorithm consists of the following steps:

1) If the ice-breaker Lo has to be removed from operation, all records on this ice-breaker are excluded from M [6].
2) Address to algorithm of processing event 4 with the point of departure P2o and the point of destination P1o.
   Output.

Algorithm for processing event 7

Event 7 characterizes an arrival of regular vessel So been received from outside to fulfil the trip Ro at the time to and begins when Zo=7. Algorithm consists of the following steps:

1) Including the record {So, Ro, 1} in M [8].
   Address to algorithm of autonomous modelling of the first stage of the trip Ro according to input data from M [7], P [8] (type of vessel Ko is determined from So) and to.
2) Conversion of data on the vessel So in M [7] into the record:
   {Ko + N, Ro, to + Tu * w5}, (10)

where Ko + N - operation on monosemantic formation of new vessel code;
Tu - average interval of vessel arrivals (selected from P [5]);
w5 - selected random quantity (determined according to P [10] when N = 5).

3) Output.

Algorithm for processing event 9

Event 9 characterizes the vessel So which has to be removed from operation at the time to. This event begins when Zo=9. Algorithm consists of the following steps:

1) If the vessel So is in M [1], the record on this vessel is excluded. Otherwise So is marked as a vessel been received from outside.
2) Records {So, Ro, t1o} and {So, t2o} are included in M [1] and M [9] correspondingly according to data of the record with minimal value t1o>to concerning the vessel So from P [11]. Output.

Algorithm for processing event 10

Event 10 characterizes the ice-breaker Lo which has to be removed from operation at the time to. This event begins when Zo=10.

Algorithm consists of the following steps:

1) If the ice-breaker Lo does not take part in escort of a convoy, i.e. in the record on this ice-breaker in M [6] t<=to and m>o, all records on the ice-breaker Lo are excluded from M [6]. Otherwise this ice-breaker is marked as an ice-breaker out of operation.

2) According to data of the record with minimal value t1o>to concerning the ice-breaker So from P [12] two records are composed in P [6] in accordance with the expression (1), and the record in M [10] is transformed to {Lo, t2o}.

   Output.

At stage 5 modelling process is being promoted and transition to determination and processing of next event is carried out. In case of modelling period expiry, stage 6 consists of presentation of essential indices (including financial ones) which characterize the efficiency of described system functioning on the basis of processing accumulated record information about operation of vessels and ice-breakers. Parameters shown in table 2 apart it demands using additional input data on vessels, ice-breakers, fulfilled trips. Approximate structure of essential data basis is described in part 4.

Modelling algorithm provides accuracy of modelling results taking into consideration casual factors' influence by estimation of essential efficiency indices of several realizations of transportation process.

4. Requirements for computer realization of the simulative model

It is expedient to carry out computer realization of the simulative model in a form of constant informational analytical system co-ordinated with the INSROP's subsystems as mentioned above. Thus, requirements for realization of the model might be presented as follows.

Information supply

Information supply must include data basis with proper structure to fulfil the following principle tasks:

1) Formation of essential input information (parameters of the system being modelled) that is shown in table 2.
2) Formation of output information which includes required operating and information indices according to data about operation indices according to data about operation of vessels and ice-breakers (table 3).
3) Giving reference information according to user inquiries.

Beside statistical processing of report information to form the basis for standards for ice- breaker sailing and support of caravans in the ice it is reasonable to use specially elaborated for these purposes model of vessels sailing in the ice.

This model is supposed to be extension and development of models elaborated in CNIIMF [3,4] on the basis of programme set LED. The basis of the model will be composed of calculation of separate vessels' and convoys' speeds, considering that convoys are under escort of different types of ice-breakers under different ice conditions. Model input data: information on ice conditions along the route, architectural technical special features of vessels intended for sailing in the ice and expert data base on tactics of ice-breaker support. Output information - speeds of given vessels and ice-breakers under different conditions.

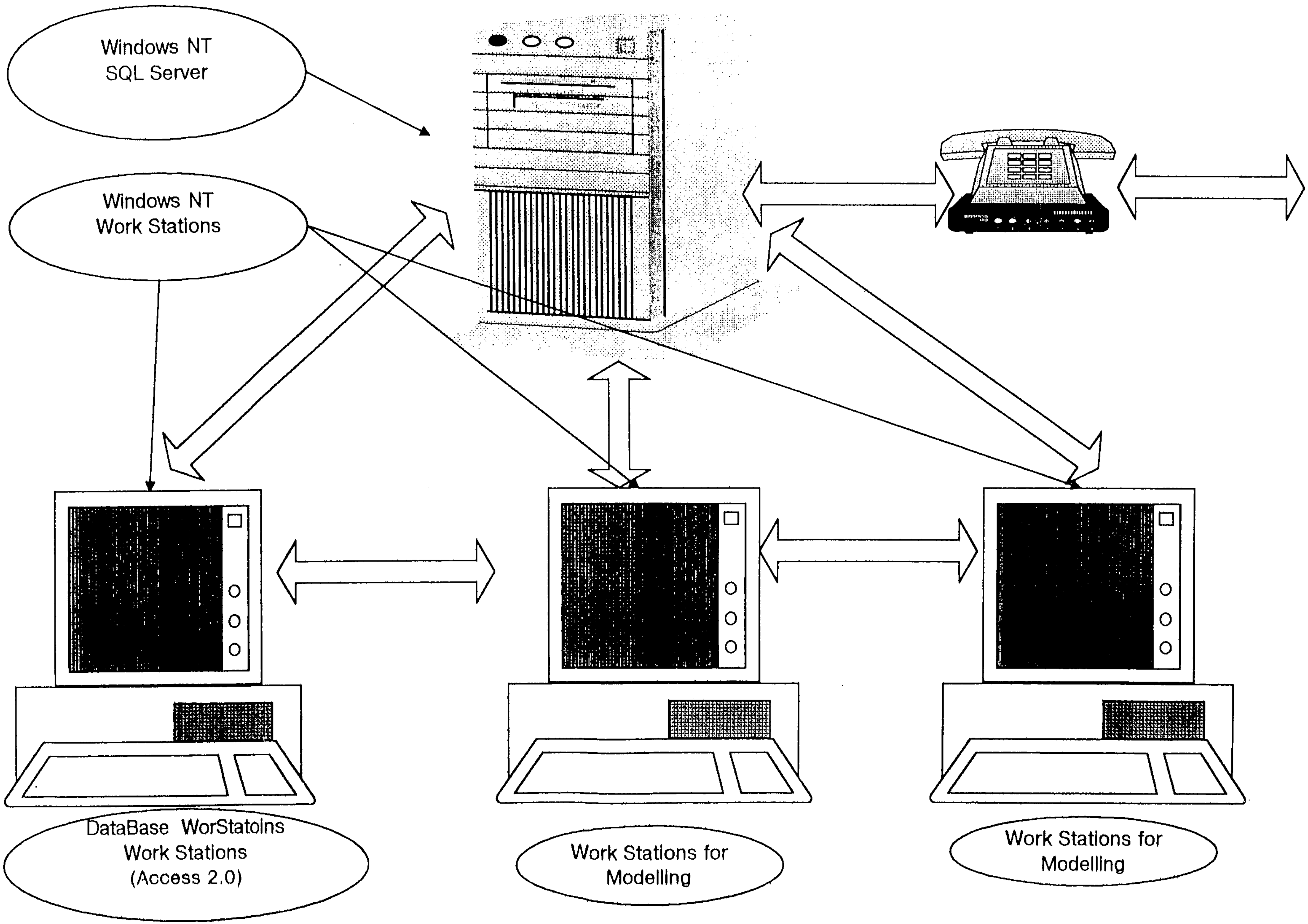
Proceeding from these requirements and considering the necessity of co-operation with other INSROP bases, the development of the information system has to be carried out in the form "client - server."

Soft - and hardware

Considering the necessity of extensive presentation of graphic information and prospects of software development, the programmes have to be elaborated for Windows 95 / Windows NT systems by principles of object - oriented programming.

Base of the system is unified data base composed by using Microsoft SQL Server. Data base interacts with automated working places (AWP) for data base servicing, modelling process control and analysis of results. Elaboration of AWP for data base servicing as "client" part is carried out on the basis of Microsoft Acces and Visual Basic means. The very modelling system is elaborated on the base of Microsoft C + + and libraries ODBS means. Visualization and analysis of results are carried out on the basis of GIS MapInfo 3.0 (picture).

Insrop Lan Modeling System



Supposed principal requirements for system server:

CPU Intel Pentium Pro/ 150 -200 mhz;
RAM - 32 - 48 Mb
HDD - 4000 - 1000 Mb

for working stations-clients of systems:

CPU Intel Pentium / 150 mhz;
RAM - 16-32 Mb
HDD - 1000 Mb
display SVGA 17" - 19" 1024 * 1024

5. Conclusions

Proceeding from presented methodology of simulative modelling of transport and ice-breaker fleets operation in the Arctic and requirements for its computer realization, it seems expedient in further work on the project to develop a special computer information analytical system concerning the Arctic.

For this purpose it is necessary to elaborate:

- composition and structure of data bases that provide computer realization of simulative model;
- software for data bases, servicing, transportation process simulation and preparing necessary output in formation.

Simulative model must be used with the employment of high-power computer to compose data bases to fulfil certain calculations by using results of other INSROP projects.

References

1. Elaboration and introduction in the shipping company of a set of tasks on simulative modelling of fleet and ports operation using a computer. Description of simulative model. CNIIMF intermediate report, 1990, 40 pp.
2. Buslenko N.P. Modelling of complex system M. "Nauka", 1968,355 pp.
3. Tzoi L.G., Bogdanov A.A. Mathematical model of vessels' motionin the ice under ice-breaker support. CNIIMF's transactions, 1983, issue 282, p. 343-352.
4. Ierusalimsky A.V., Bogdanov A.A. Technical economic grounds for using means to improve cross-ice abilities of transport vessels and ice-breakers. CNIIMF's Transactions, Optimization and organization of fleet and port operations, 1987, p.87-104.

APPENDIX

REVIEWS BY JUHANI SUKSELAINEN AND ANITA LUKKA

Observations on the report "The methodology of simulative modelling of transport and icebreaker fleets operation in the Arctic" by A. Schelkanov and J. Kelberg, CNIIMF.

The report describes a basic methodology for modelling of transport fleet management including icebreaker assisted convoy operation. This kind of model structure is necessary when tackling with complicated transport fleet structures in general. In light to moderate ice conditions this kind of modelling certainly is capable of providing useful information as operational difficulties due to ice conditions are rather easily modelled using a few parameters describing ice conditions and ship and icebreaker performance in various not too severe environments. To what extent this kind of modelling is applicable for the conditions of NSR, should certainly be well in hands of CNIIMF, however, as they have a long record of designing ships to those conditions.

The computer capacity certainly is not a problem in applying the described simulation algoritm in case where ship and average seasonal ice conditions are used in determining delays to be expected. Most part of the computer power is just needed for the animation of presentation graphics only.

As the adjacent tasks of the project "Survey of logistics models" have not been presented in the material supplied, it is rather difficult to judge in detail, what is directly expected as result of the present tasks in the whole program. I can assume, however, that sufficient detail information of ship and icebreaker performance is available for the authors to continue with practical applications of the presented programme structure to gain usefull results in practical simulation excercises for the purposes of INSROP.

To benefit future readers of the report, a linguistic review would help to clarify the terminology used. Probably there is a glossary available for the INSROP, which I do not know.

To summarize, the quality of results of fleet operation simulations stands or fails with the representativity of parameters and distributions available for the intended task.

Espoo, Finland 28.02.1996

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Review of INSROP project III.06.1 "Survey of Logistics Modelling "
Part 2: The Methodology of Simulative Modelling of Transport and Icebreaker Fleet"
by A. Schelkanov and J.Kelberg

The paper to be reviewed was treated with the principle as any paper intended for international publication. The INSROP intention for working paper may have a more lenient approach.

For the review, also the Part 1 discussion paper was kindly sent.

In the review I will specially consider language, introduction, and some aspects of the simulation model.

LANGUAGE: There are some typing errors, some of which even have an effect on the interpretation. These should be checked and corrected. Otherwise the paper was well written and easy to read.

INTRODUCTION: The proposed working paper relies to the discussion paper "Survey of Logistics Models" by A. Schelkanov, J. Kelberg and R. Gryazev, as Part one of the project. This paper is very interesting in itself, and is used to propose the second paper. As the discussion paper is obviously not available to the readers of the 2. paper, I would suggest that some of the ideas and background be included in the introduction, instead of referring, and especially section 3.3. of the discussion paper could be used as background material in the paper intended for publication.

SIMULATION MODEL is presented as a collection of ALGORITHMS, which is a somewhat ambitious way of describing a STEP or a SUBPROCESS in the actual model. I would suggest that the word algorithm be replaced by a more appropriate term.

THE MODEL would benefit a lot by a flowchart description, which is a typical way of presenting the model principle. Now the reader has some difficulties in seeing the model as whole.

THE VARIABLES of the simulation model are very well defined, and fit the model well, and tell a lot of the model.

MODEL SIZE is not discussed. The number and structure of the variables suggest that the model in practice might be fairly large. The size is one of the main factors in the practical application of the simulation models, and when the paper is intended for more wide spread publication, this aspect might well increase the value of the paper in discussing its applicability into practice.

MODEL TEST. There was absolutely none. This should, however, be presented, even as a preliminary, simple, test, using test data.

DATA was discussed, and this was good. In the model test, however, computer generated test data could be used, if actual data is missing.

The model itself is a very interesting case, with practical case application possibilities.

CONCLUSION: the paper is worth developing into a significant publication, but a simple test case should be done, and model outline as a flowchart is required.

I appreciate this chance to get to know INSROP and to acquaint myself in this project.

Yours sincerely, Anita Lukka
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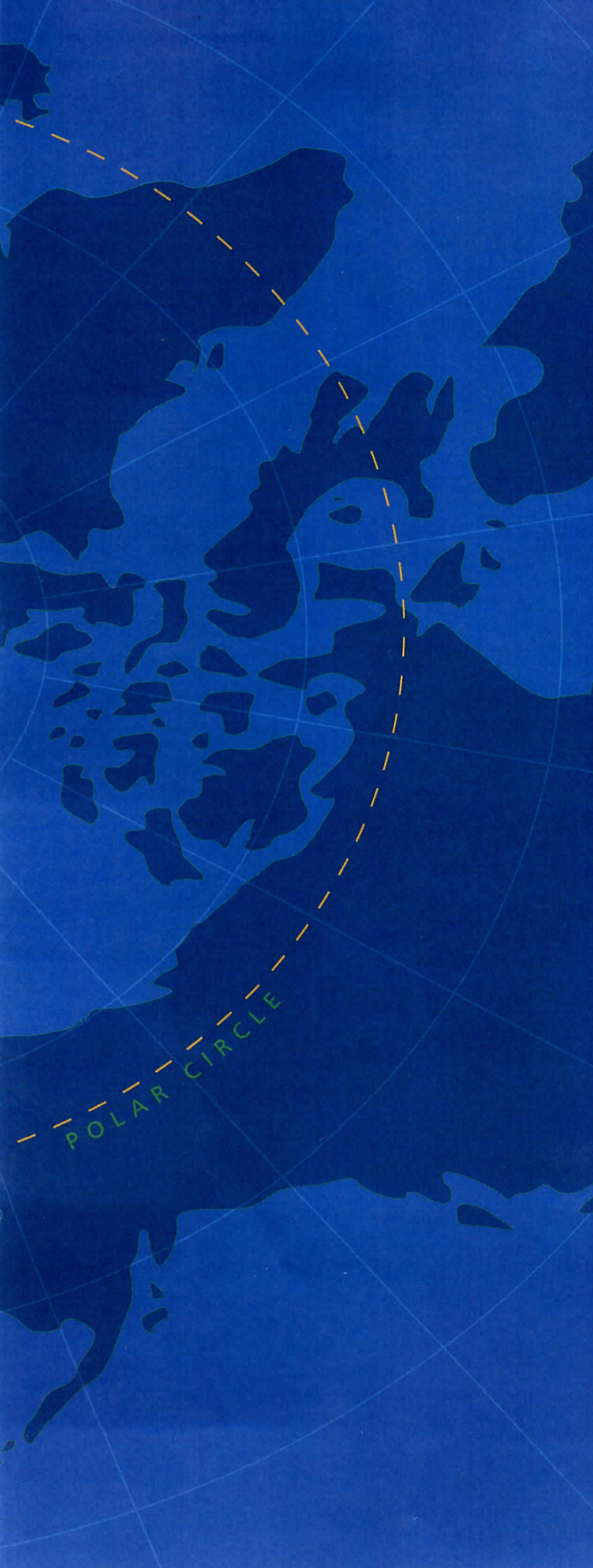
The answer to a Rewiew by Anita Lukka

We are grateful for consideration of our work and valuable remarks however we should necessary to note following.

The first phase of work according to the plan provided fulfilment only of the suvey of logistic models carried out in Russia for the last period and development of model, software of maintenance and the test drivve of model are provided to be carried out on the second phase of work on INSROP

A. Schelkanov and J.Kelberg



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 Sasakawa 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 stock-holding 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 multi-disciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.