https://www.sworldjournal.com/index.php/swj/article/view/swj06-06-119
DOI: 10.30888/2663-5712.2020-06-06-119

УДК 652.01.52

ESTIMATION RISK OF NAVIGATION
ОЦЕНКА НАВИГАЦИОННОГО РИСКА

Kulbatsky A. A. /Кульбацкий А.А.
National University «Odessa Maritime Academy», Didrihsona 8, 65000
Национальный университет «Одесская морская академия», Одесса, Дидрихсона,8, 65000

For research of use of special navigation aids (SNA) in the extreme situations connected to safety of navigation application of the mathematical modeling spent on the computer which allows to make quickly evident model is possible and to obtain the necessary data on system "way – vessel - the navigator".

Keywords: *Special navigation aids, risk, safety of navigation .*

INTRODUCTION

For research of use of special navigation aids (SNA) in the extreme situations connected to safety of navigation application of the mathematical modeling spent on the computer which allows to make quickly evident model is possible and to obtain the necessary data on system "way – vessel - the navigator".

Modeling applies and when direct experiment is impossible.

However the received data will reflect the valid behaviour of components of system with some error dependent on adequacy of model and SNA is a lack of mathematical modeling.

Hence, the primary goals of natural tests, researches on the basis of mathematical modeling consists in the following:

- check of new model, design, method,
- estimation of variants SNA, preliminary definition of their characteristics, reception of the initial information for acceptance of basic decisions on development SNA;
- working off of experimental sample SNA, specification of values of parameters and admitted limits of their changes, working off of the basic receptions of operation SNA;
- tests of a batch production for definition of quality of its work on performance of the functions assigned to it;
- specification of structure and parameters of mathematical model SNA in various conditions of operation and on this basis of forecasting of its behaviour.

Hence, the decision of many problems of designing, tests and is impossible for operation without formation of mathematical models of a static and dynamics SNA. Models have great value in connection with a problem of a prediction of behaviour of system under various conditions of operation. Mathematical modeling is one of effective tools of research of complex systems. It speaks that mathematical modeling allows to study behaviour, to estimate parameters of system and to predict influence of their change on functioning of all system.

Results of research on mathematical model of dynamic characteristics of system, its separate elements characterize scales of their real dynamic mistakes, and allows to plan ways for their elimination or correction — in it will consist one of the main tasks of modeling. Hence, as a result of modeling as the result of studying of model arises the new information on object researched by him.

Navigation — process, which separate stages is necessary to make collectively, for example, navigation in areas of brisk navigation, anchorage on the road, sailing to port, passage of waterways and channels, saving operations, etc. Therefore it is important; that in these conditions all participants of process should be in concept or the term to put the same sense, otherwise the basic normative documents will not work. There is a special section " Terms and definitions " in a number of the important normative documents (the International conventions, Rules of the Register) with this purpose. However a lot of concepts are not determined not only in normative documents, but also in the special literature. Uncertainty of concepts generates debatable concerning their maintenance and subjectivity concerning their application. For example: terms " safe speed ", "average", "negligence", "risk", " safety of navigation ", etc. Researches have shown, that 49 % of navigators cannot define the term " safety of navigation ", 11 % do not understand the term " safe speed " and 22 % cannot appoint it, 15 % cannot define as the term "average", and 35 % — to the term "risk".

Ergonomics — a science studying problems of the working person. A subject of ergonomics is labour activity of the person, and object of researches — system "person – the computer - environment". These researches are spent with the purpose of optimization of working conditions, increase of its productivity, safety and protection working. The ergonomics study functionalities and abilities of the person in labour process, form main principles of profecional training of the staff, expose requirements to the equipment, a workplace, a control panel with a view of the maximal adaptation of the equipment to ergonomic characteristics of the person.

In the system analysis cases when the system receives properties which do not follow from the properties which are included in this system of elements are considered.

The system " the person — the computer " has hierarchical structure at which top there is a person who is carrying out functions of the general manager of an element, the link accepting the decision. The important condition of reliable functioning of system " the person — the computer " is professional competence of the person. Professional competence develops of knowledge, skills, discipline and conscientiousness.

The economic aspect consists in the analysis of building and emergency expenses and in definition of economic policy in safety issues on the basis of this analysis. A ultimate goal of any economic activities is maximization of its criterion function. From a position of economy it is profit which represents a difference between incomes and charges. But any multicomponent problem is maximized only on one parameter. Therefore statement of a problem – optimization of incomes and charges will be correct in view of a condition of system « a way – a vessel – the navigator ». One of significant sources of charges is expenses for averagely susceptibility.

Decrease in a level of emergency charges probably various methods: introduction of new technologies, technics, constructive decisions, organizational actions, etc. Annually shipowners incur million commercial losses. The most part of this sum falls at cases of damage, damage or loss of a cargo in a way. This so-called technological averages which occupy one of the first places on uncontrolability. Technological averages are not limited only to damage or loss of a cargo — they can cause damage and even destruction of a vessel. The cargo as an element of transport system renders the big influence on safety of navigation of a vessel. This influence depends on transport properties of a cargo, conditions of its transportation, technological compatibility with other cargoes, technological conformity of ships and transport characteristics of a cargo.

Researches of averages susceptibility of fleet for last years show, that a basis of these averages, infringements of technology of loading of courts or rules of transportation of cargoes are. All this makes lawful such allocation of averages in separate group " technological averages " for detailed studying their reasons and the nature of occurrence. Studying of the reasons of " technological averages " will allow to reduce their number and by that to increase safety of navigation. The reasons of technological averages are insufficient developing technological specifications, constructive imperfection and discrepancy of technological normative base, infringement shippers and the stevedore companies of technology requirements on container and stacking of the cargo, the insufficient control over crew behind observance of technology requirements.

Maintenance of navigating safety is a necessary condition of protection of a life on the sea, environments from pollution and effective operation of fleet. Spent scientific researches, technical development and organizational actions are directed on increase of reliability of navigation. Reliability of navigation depends on a condition of a way, a vessel and the operator. It is considered to be the basic parameter of reliability of navigation absence of navigating incidents and failures during the set time interval. All cases of a contact of a ground concern to navigating incidents, owing to refusal what - or the making not determined system « a way - the vessel - navigator ». On transport many domestic and foreign scientists were engaged in questions of reliability. Offers according to reliability in aircraft are considered in works prof. Molokanov M.G., for navigation on internal waterways - prof. Olshamovskiy S.B., prof. Zemljanovskiy D.K., etc., on sea transport prof. Kondrashihin V.T., prof. Kozyr L.A., prof. Makarov G.V., d.s.c. Shevchenko A.I., prof. Aleksejchuk M.S., etc. Offered criteria can be divided into two basic groups. The first group includes the criteria which are taking into account statistics of average susceptibility and losses, the second group - the criteria estimating operative navigating conditions. The criteria of the first group submitted in tab. 1.

Advantage of criteria of the given group is that on the basis of statistics of emergency incidents it is possible to allocate the reasons and to estimate influence of various factors on breakdown susceptibility, to define(determine) size of losses and to develop actions for decrease in a level of average susceptibility. The considered criteria assess the past events as conditions of navigation change faster, than accumulation of statistics of failures. Therefore the given criteria do not allow to estimate navigating conditions and to take operative measures.

The criteria submitted in tab. 2 concern to the second group.

Table 1

Criteria of reliability of navigation

№	The analytical form of record	The name
1	$K_Q = A / Q$	By quantity A of averages to transported cargo Q
2	$K_{QL} = A / (Q\ L)$	On volume of the executed work, i.e. by quantity A of averages to transported cargo Q on distance L
3	$K_L = A / L$	On average distance L of transportation 1 т a cargo
4	$K_N = A / Nc$	On structure of fleet Nc
5	$K_{NL} = A / (NcL)$	On vessel – to kilometers.
6	$K_O = R / A$	Parameter of weight of averages, i.e. share of losses R on an average.
7	$K_N = 365 \cdot A/(N_C \cdot T_Э \cdot \tau)$	Dimensionless factor of reliability of navigation in view of factor of running time τ, the period of operation $T_Э$, structure of fleet N_C, average susceptibility for a year
8	$D = N_A \cdot 10^6/(n_A \cdot L_A \cdot 365)$	Dimensionless factor of incidents, in view of factor of failures n_A on a site in length L_A and daily intensity of movement N_A
9	$d = D / D_{MIN}$	Number of incidents
10	$K_г = f\ (t)$	Factor of readiness in view of time of a time between failures.

Table 2

Criteria of navigating safety

№	The analytical form of record	The name
1	$y = D / m_D$	The attitude of a distance up to danger D to size of positions error (СКП ОМС) m_D
2	$y = 0.5\ Bф / \sigma_X$	The attitude halfwidth waterway Bф to size of lateral evasion of vessel σ_X
3	$y = B_F / 2M$	The attitude of width of a waterway B_F to size of error (СКП) of definition of a place of vessel (ОМС) 2M
4	$K = H – T_C$	The size clearance K is estimated by a stock of water under the bottom of a vessel with draft the T_C on depth H.
5	$K_i = f\ (\Delta H_i)$	The information criteria which are taking into account volume of the acting information ΔH_i.
6	$U = B \cdot H \cdot R \cdot S \cdot C$	The generalized criterion showing connection of factors, taking into account width of ship B, depth H, radius of curvature R, visibility range S and features of current C.

The generalized criterion 6 offered prof. Zemljanovskij D.K. shows probability connection of the factors which are taking into account width of ship B, depth H, radius of curvature R, visibility range S and feature of current of C. But the given criterion does not take into account completeness of the acting information, at use of means of navigation. Therefore it is necessary to specify factor for different types of courts and structures since factors B will change, R, C. Information criteria 5 allow to estimate completeness of the acting information and supplement criteria 1-3. The size clearance shows a stock of water under the keel, but does not estimate approach danger. The criterion 2 does not take into account width of a vessel, in result the estimation turns out overestimated.

Therefore for an estimation of navigating safety we shall take advantage of criteria 1,3. One of lacks of criteria is that they do not take into account completeness of the acting information at use of means of the navigating equipment.

For reduction of influence of the above-stated lack it is offered to enter factor of completeness of navigating information Ki. The executed researches of a condition of means of the navigating equipment on the Danube, and their influences on an information field of the navigator, have allowed to receive coefficient of quantitative estimation navigation information K_i. The estimation of navigating safety will become

$$P_H = Ki \cdot f(y), \qquad (1)$$

The considered criteria of navigating safety allow estimating conditions of navigation, but do not reflect connection between probability in size of risk and economic efficiency of expected result. Researches of average susceptibility of fleet show, which owing to wrong decision-making and unreasonable risk occurs about 40 % of averages, owing to « the human factor ». Therefore, the choice of criterion which would estimate navigating safety is necessary for decrease in a level of average susceptibility, enabled the navigator operatively to take measures, showed border between reasonable and unreasonable risk, represented the received information in the form convenient for the navigator.

Last years in different areas of scientific researches of transport system, domestic and foreign scientists studied questions of an estimation of risk. To these questions works in economy and are devoted to the industry, in aircraft and motor transport, on sea and river fleet.

In view of these development the offered criterion of an estimation of factor of risk And expresses connection between expected economic benefit E with set probability P_H and possible losses R as a result of averages. Economic benefit depends on size of the freight, charges of a vessel in voyage and possible losses at default of treaty provisions about transportation. The size of losses from failures is received as a result of researches of statistics of average susceptibility in the given area. The limit of reasonable risk is defined by a parity

$$P_H \cdot E \geq (1\text{-}PH) \cdot R, \qquad (2)$$

$$A = \frac{P_H \left(\Delta F - \left(\sum_{i=1}^{n} Si / Vi \right) \cdot C_X - C_{CT} \cdot t_{CT} - b_3 \right)}{(1\text{-}P_H) \cdot (\mu_n \cdot Д_Ч + b_2)} \geq 1, \qquad (3)$$

$$\Delta F = f \cdot Д_Ч - (C_X \cdot t^1{}_X + C_{CT} \cdot t^1{}_{CT} + b_1 + C_X \cdot t^{11}), \qquad (4)$$

$$\mu_n = \frac{\sum_{i=1}^{n} ТУ_{Ni}}{n_n \cdot Д_ч} \quad (5)$$

where P_H – an estimation of navigating safety on the given site;

Si – sailing distance of the site gone with constant speed Vi;

C_X, C_{CT} – operational charges of a vessel at the sea and in the port;

t_{1CT}, t_{CT} - time in the port in the first part of voyage and the period of expectation of improvement of navigating conditions on a site a waterway;

t_{11} - necessary time for end of voyage;

t_{1X} - running time in the first part of voyage;

$b_{1,2,3}$ - the additional charges connected to the executed part of voyage; at default of conditions of transportation of a cargo; with passage limited part of waterway.

$ТУ_{Ni}$ - technical losses as a result of a considered kind of averages in the given area of navigation;

nn – quantity of the considered cases;

f - the charter rate;

$Д_ч$ - quantity of a cargo;

For definition of a possible waiting time of improvement of navigating conditions we shall take advantage of expression

$$t_{CT} = \frac{(\Delta F - b_3 - (\sum_{i=1}^{n} Si/Vi) \cdot C_x) - (1/P_H - 1)(\mu_n \cdot Д_ч + b_2)}{C_{CT}}, \quad (6)$$

The algorithm of an estimation of risk is submitted on fig. 1.

The analysis of theoretical calculations and the given voyages of courts at following on ports p. Danube shows serviceability of an offered technique for an estimation of border of risk and acceptance of the optimum decision by the navigator. Results of calculations of factor of risk for ways of the control of a place of a vessel (1 - visual, 2 - radar-tracking, 3 - floating means of a navigating protection) and at change of a navigating information field during following by a river waterway on the Danube, are submitted on fig. 2 - 7.

Results of calculations of the period of expectation of improvement of conditions of navigation during following by a river waterway on the Danube are submitted on fig. 8 - 10.

SUMMURY

For increase of safety of navigation, it is necessary:

To support corresponding depths in channels, on limiting sites of the river, carrying out bottom works;

To improve a protection of navigating dangers on river sites modern means of a navigating protection;

To apply on modern SNA for controlling of ship’s position to maintenance of necessary reliability of navigation;

To increase efficiency of transfer of the navigating information on a condition and position of means of a navigation aids on river’s waterways;

To calculate and construct routing schedules of accuracy, reliability, speed limits of sailing, limits of reasonable risk on limiting sites;

To create a uniform control system of the traffic on the Danube.

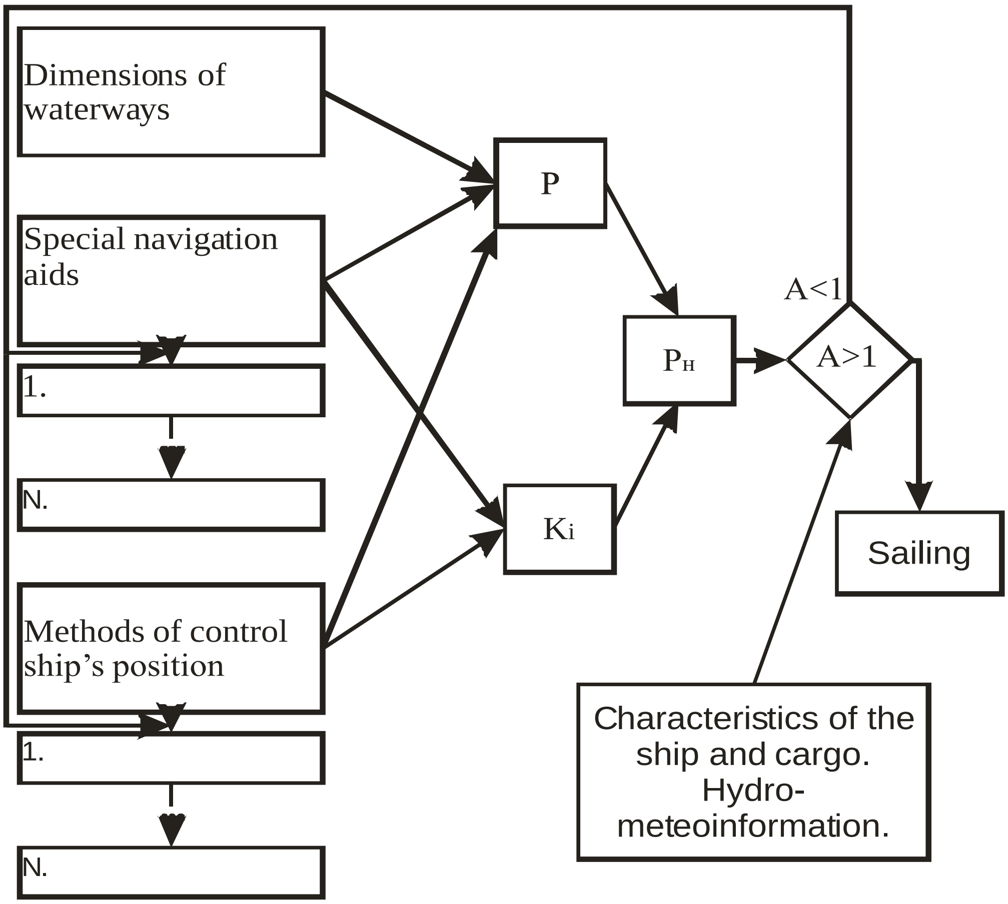

Fig.1 Algorithm of the estimated risk

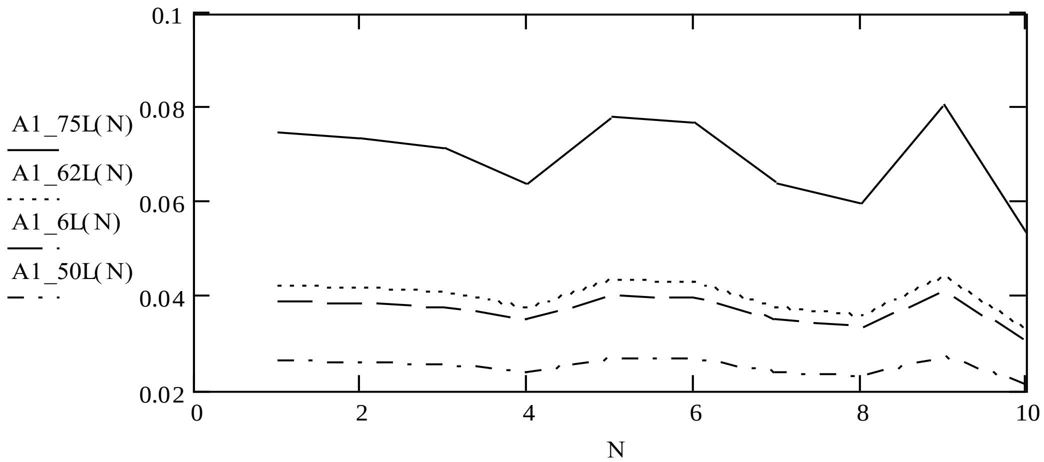

Fig. 2. Routing schedules of an estimation of risk on a site r. Danube at a pilot's method.

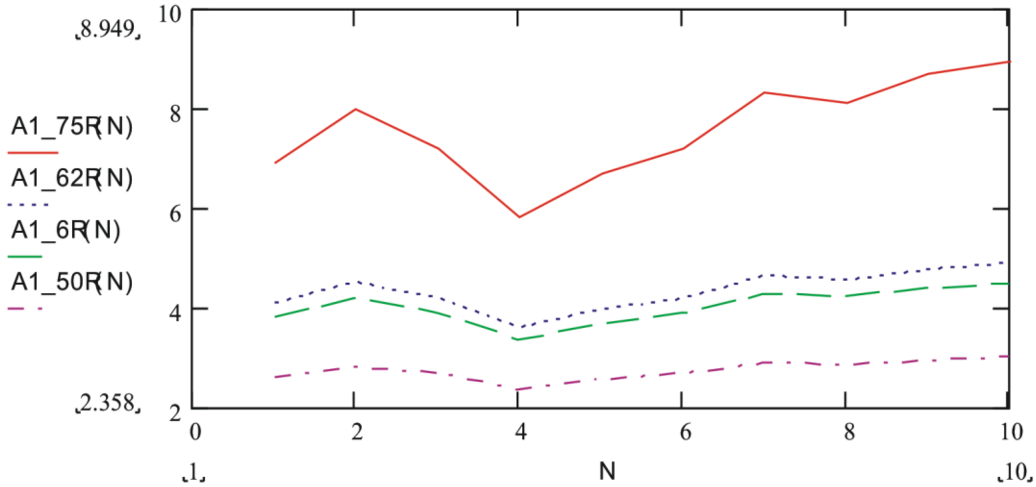

Fig. 3. Routing schedules of an estimation of risk on a site r. Danube at a pilot's method.

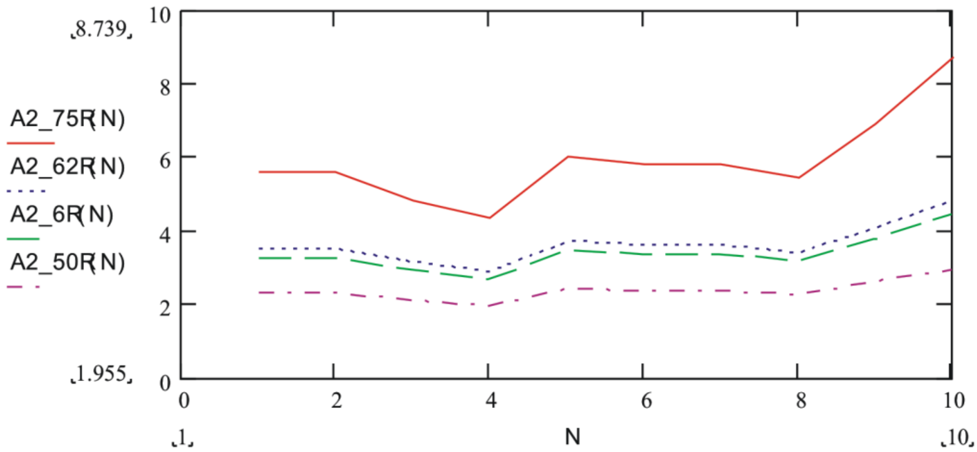

Fig. 4. Routing schedules of an estimation of risk on a site r. Danube at a radar-tracking method.

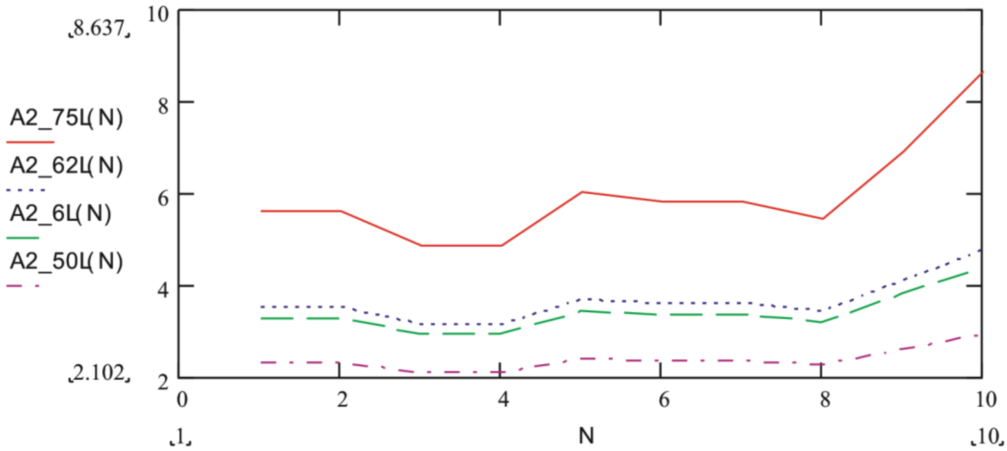

Fig. 5. Routing schedules of an estimation of risk on a site r. Danube at a radar-tracking method.

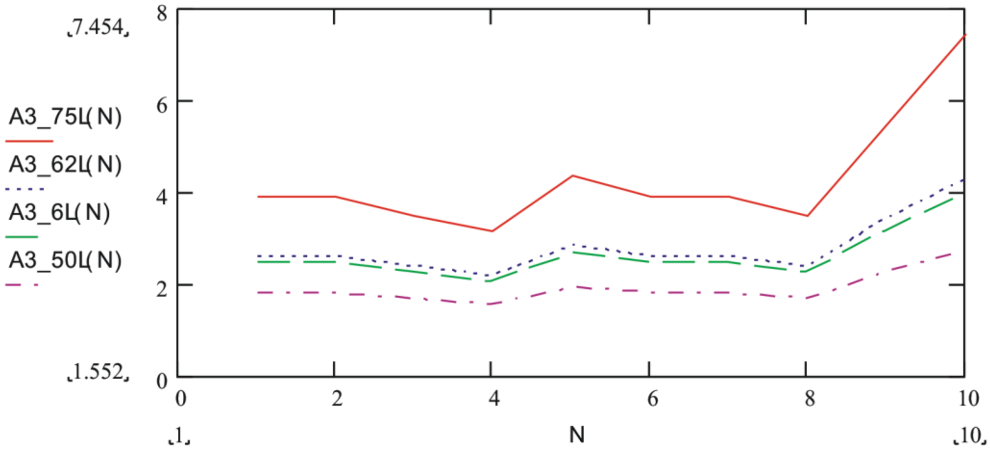

Fig. 6. Routing schedules of an estimation of risk on a site r. Danube at use navigation aids.

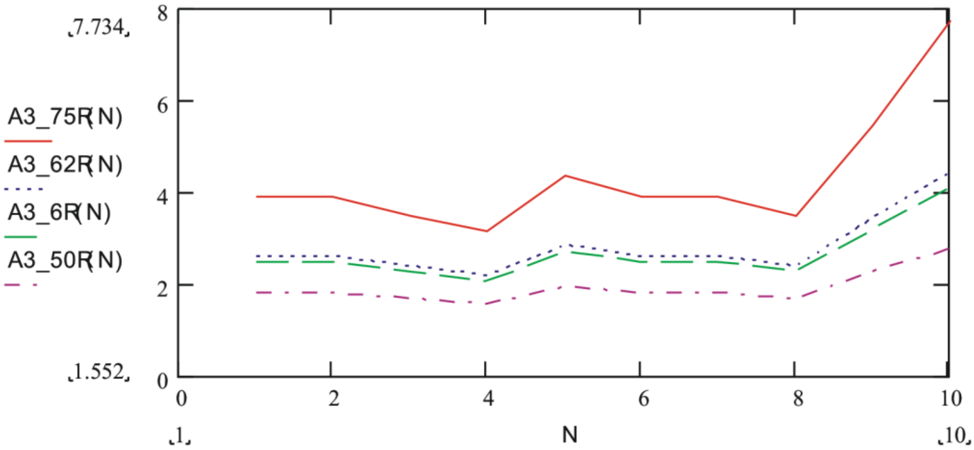

Fig. 7. Routing schedules of an estimation of risk on a site r. Danube at use of means of navigation aids.

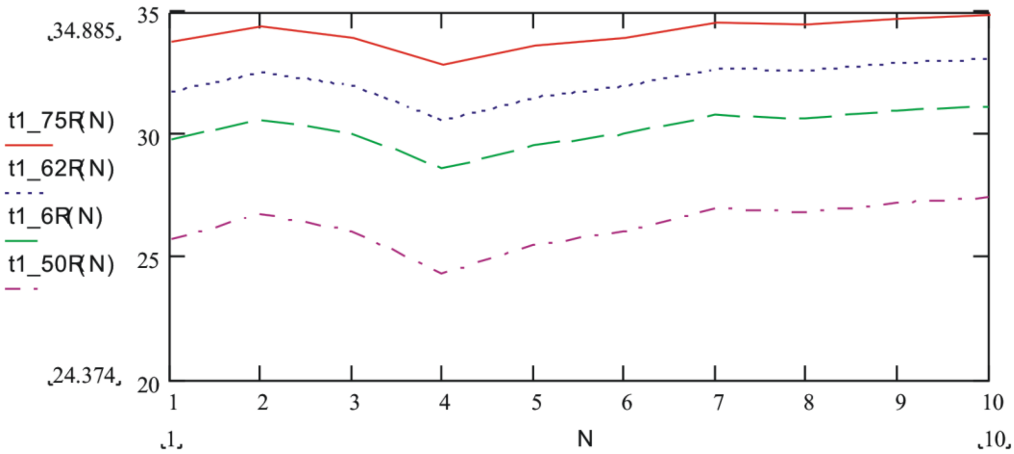

Fig. 8. Routing schedules of the period of expectation on a site r. Danube at a pilot's method.

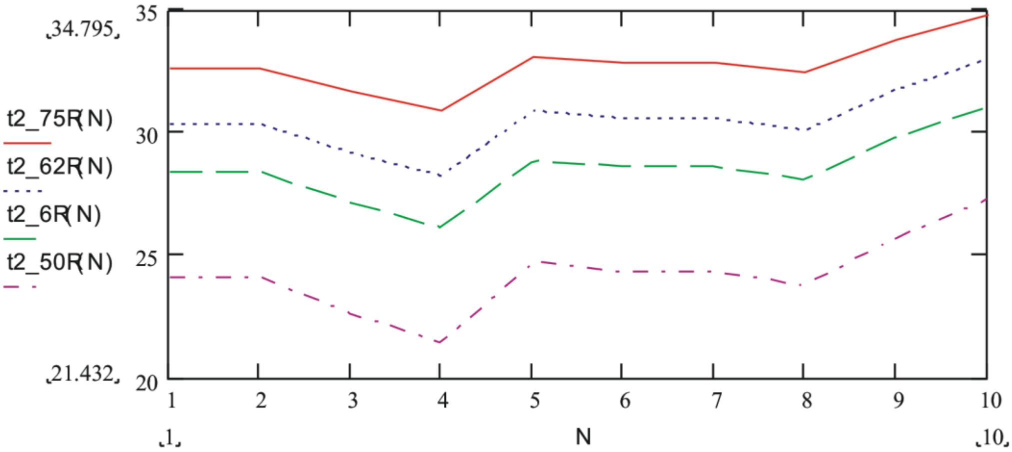

Fig. 9. Routing schedules of the period of expectation on a site r. Danube at a radar - tracking method.

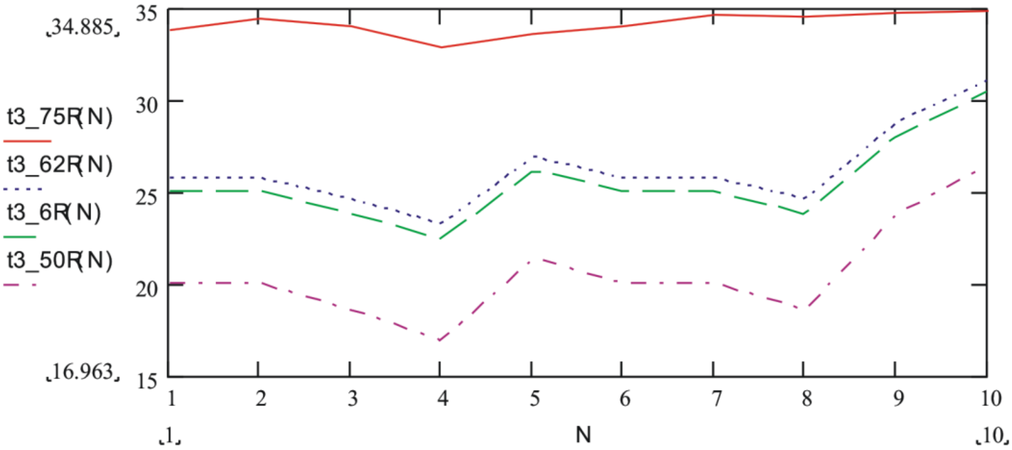

Fig. 10. Routing schedules of the period of expectation on a site r. Danube at use of means of a navigation aids.

Аннотация. *Для исследования использования технических средств навигации (ТСН) в экстремальных ситуациях, связанных с безопасностью судоходства возможно применение математического моделирования, проводимого на ЭВМ, которое позволяет быстро произвести наглядную модель и получить необходимые данные о системе «путь-судно-судоводитель».*

Ключевые слова: *Технические средства навигации, риск, навигационная безопасность*