UDC 519.254
DOI: 10.18372/2306-1472.74.12291

**Illya Tykhonov**

# METHOD OF THE STATISTICAL DIAGNOSTIC OF RELIABILITY OF SHIPS' EQUIPMENT

State University of Infrastructure and Technologies
9, Kyrylivs'ka str., 04071, Kyiv, Ukraine
E-mail: itykhonov@i.ua

**Abstract**

***Purpose:*** *the purpose of this article is to present the method of the statistical diagnostic of ship onboard electronic equipment reliability, using of probabilistic model of stream of refuses on the Neyman-Pirson's plausibility criteria.* ***Method:*** *the article describes the method of account these criteria which allow to increase a control level on the state of reliability of ship onboard electronic equipment with using of the statistical diagnostic.* ***Results:*** *on the basis of the analysis conducting received in relation to the level of reliability of ship equipment made decision concerning to possible declining of equipment reliability level and terms and volume of his technical service.* ***Discussion:*** *the proposed method is the methodological basis for search of extremums of Neyman-Pirson's criteria of the supervisions terms and permit to provide the diagnostic of ship onboard equipment reliability.*

**Keywords:** parameter value; ships' electronic equipment; statistical diagnostic; technical service.

## 1. Introduction

At this time up-to-date devices, systems and facilities that allow to promote efficiency of the use of ships on water ways during carriage of cargoes, are actively used in a world trade fleet.

At the same time, in connection with the development of technologies in last years, shipowners minimize the quantity of ships' crewmembers, that does not allow in proper time in full volume to conduct the technical diagnostic of ships' onboard electronic equipment.

Taking it into account and for prevention of refuses and breakages of ship equipment and mechanisms, actual is a task to create conditions for the maximum possible full and complete automatic diagnostic of ships' equipment, first of all the basic ship systems: ships' navigation complex with its equipment, and complex of management of ships' main propulsion machinery.

For decide the task, it is necessary of providing of ships' onboard electronic equipment reliability level needed. It can be carried out by using approach of the statistical diagnostic. This article is sanctified to the decision of this problem. Without its realization the permanent reliable automated control for activity of ships' electronic equipment is impossible.

## 2. Analysis of the last researches and publications

In accordance with the analysis of scientific and technical researches and publications [1,4,7-9], at this time there is the accepted approach in relation to the estimation of reliability of technical equipment as function of sentinel work between the certain parts of time. Taken into account also the recommendation of providers in relation to work hours to the breakage of equipment. By the corresponding State standards of Ukraine certain methods of statistical evaluation of indexes at the various graphic plans of works are demand. But, as appointed in publication [4,6,9], often, mainly in the conditions of unfavorable weather conditions, services upon a certain plan do not answer a plan with standards required.

In publications [1,3,4,6,7] are given approaches concerning realization of statistical control of reliability of equipment.

But, concretely reasonable recommendations in relation to a choice and calculation of statistical figures for increase of level of ships' electronic equipment reliability, it is not prepared till now.

### 3. Aim and objectives of the researches

To prepare the method of the statistical diagnostic of reliability of ships' equipment taking into account the probabilistic model of stream of refuses on statistics of the Neyman-Pirson's plausibility criteria.

### 4. Materials and methods of research with the grounding of the previous scientific results

The probability model of the stream refuses according to the Neyman-Pirson's plausibility criteria, which account the instability of observation conditions for the Poisson distribution, taking into account the model of the stream refuses of the ships' equipment, is based on the statistical hypotheses $H_0$ and $H_1$, which can be classified as follows:

statistical hypothesis of $H_0$ – at this value of actual amount of refuses of $n_ф$ ships' equipment as for *i* period of exploitation the parameter $n_{H_0}$ of size distribution law of amount of refuses of *n* equals to the statistical evaluation of the expected quantity of refuses $\hat{n}_ς > 0$ for this control period;

statistical hypothesis of $H_1$ – at this value of actual amount of refuses of $n_ф$ of ship equipment for *i-period* of the exploitation parameter $n_{H_1}$ of distribution law of refuses amount n exceeds parameter $\hat{n}_ς$ ($n_{H_1} > \hat{n}_ς$, when $n_{H_1} \neq \hat{n}_ς$) [1,4,5,6,9].

Where parameter $n_{(H_1)_i}$ is a value of the parameter of distribution law of size of refuses amount of *n* for *i* period that answers the hypothesis of $H_1$.

The value of parameter $\hat{n}_{ς_i}$ is the function of statistical evaluation of the expected value of parameter of refuses stream $\hat{Z}_{з_i}$ of the technical facilities.

For its determination value of parameter $\hat{Z}_{з_i}$ is used, which got on results prognostication, if a sentinel sort of statistical evaluation values of actual value of parameter of stream of refuses parameter $\hat{Z}_ф$ is non-stationary.

For a verification of hypotheses, it is necessary to use the statistical data's and define the critical area of statistics, which is determined by values α and β.

The statistical data's on general loss of ships in the world for a period 2010-2015 on the ship's types [10-12] are indicate in the Table 1 and on Fig. 1.

*Table 1*

**Total losses of ships in the world for a period 2010-2015 on the ship's types**

| Types of Ships | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|
| Dry cargo | 60 | 37 | 61 | 41 | 31 | 36 | 266 |
| Bulkers | 11 | 14 | 9 | 15 | 4 | 6 | 59 |
| Passenger's | 3 | 7 | 7 | 8 | 10 | 4 | 39 |
| Tugs | 7 | 2 | 6 | 7 | 7 | 7 | 36 |
| Chemical tankers | 5 | 2 | 8 | 10 | 2 | 2 | 29 |
| Ro-Ro | 1 | 3 | 4 | 2 | 5 | 4 | 19 |
| Other types | 3 | 5 | 3 | 6 | 4 | 2 | 23 |
| Container's | 5 | 3 | 6 | 4 | 4 | 5 | 27 |
| Suppliers | 2 | 2 | 3 | 2 | 3 | 2 | 14 |
| Barges | 1 | 0 | 0 | 3 | 1 | 0 | 5 |
| Dredgers | 2 | 2 | 2 | 0 | 1 | 1 | 8 |
| Oil tankers | 3 | 3 | 1 | 0 | 1 | 0 | 8 |
| Gas tankers | 1 | 1 | 1 | 0 | 0 | 0 | 3 |
| Grand total | 104 | 81 | 111 | 98 | 73 | 69 | 536 |

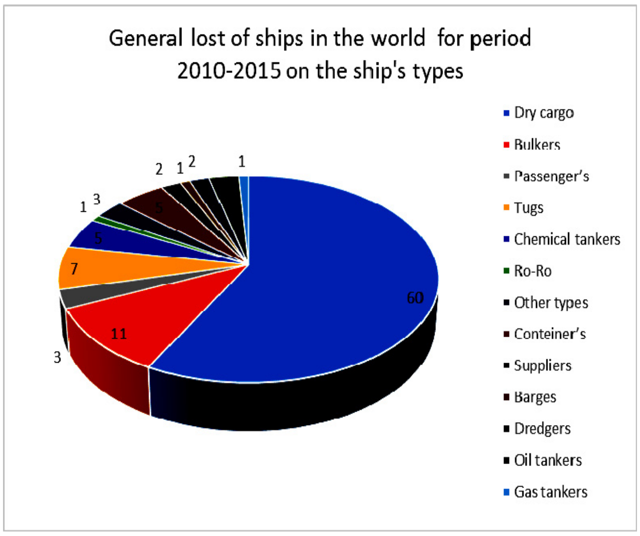


Fig. 1.

The statistical data's on causes of total losses of ships in the world for a period 2010-2015 [10-12] are indicate in the Table 2 and on Fig. 2.

Values α and β, which determine the level of meaningfulness and function of power of criterion, can be certain not strongly. But maximal authenticity of acceptance or rejection of one of hypotheses answers a minimum value α and β.

As a value α and β depends from the obtained statistical data of $n_ф$ , from the parameter $n_{H_l}$ and terms of supervisions $\hat{n}_ξ$, then minimum values $α$ and β will be determined by the area of possible values for the given terms of supervisions and obtained and received statistical data of cases of shipboard equipment failure, which were results of the above emergency events.

*Table 2*

**Causes of total tosses of ships in the world for a period 2010-2015**

| Causes | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|
| Submerged | 64 | 45 | 55 | 70 | 50 | 63 | 347 |
| Wrecked/ aground | 23 | 28 | 26 | 21 | 18 | 12 | 128 |
| Fire/ explosion | 11 | 8 | 13 | 15 | 6 | 3 | 56 |
| Collision | 10 | 3 | 5 | 2 | 2 | 3 | 25 |
| Machinery damage | 4 | 6 | 15 | 2 | 5 | 2 | 34 |
| Hull damage | 4 | 3 | 6 | 1 | 4 | 2 | 20 |
| Miscellan. | 6 | 1 | 1 | 1 | 2 | 0 | 11 |
| Hall contact | 0 | 0 | 2 | 0 | 1 | 0 | 3 |
| Piracy | 2 | 1 | 0 | 0 | 0 | 0 | 3 |
| Missing | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Grand total | 125 | 95 | 123 | 112 | 88 | 85 | 628 |

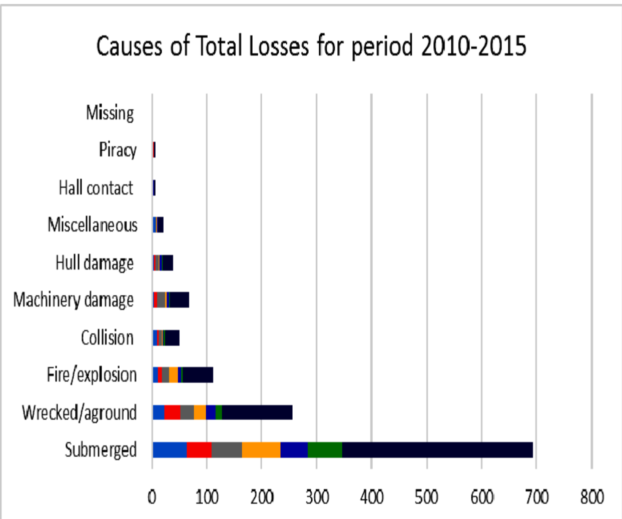


Fig. 2.

In this case a task as follow: search of extremums of statistics of criteria of Neyman-Pirson's for these terms of supervisions [1,2,5,9]:

Chart of dependence of value of statistics of criteria $W(n_{H_l})$ of the parameter $n_ф$, $n_{H_l}$ at the various conditions of supervisions on the Neyman-Pirson's criteria, is given on the figure 3.

Figures shows that to every values of parameter $n_ф$, $\hat{n}_ξ$ answers a maximal value to the parameter $n_{H_l}$, which is determine the lower level for value $A \geq \frac{1-β}{α}$ . Thus the minimum value of criterion is arrived when parameter $n_{H_l}$ → ∞. But, as figures shows, when parameter $n_{H_l}$ > *6* reduction to the function is considered much slowly. And when $n_{H_l}$ = *7* for different $n_ф$ the function takes on a value less than 0,5.

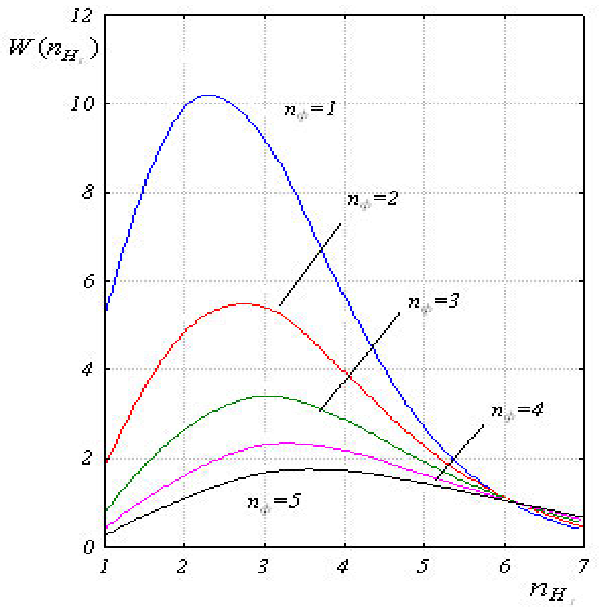


Fig. 3. Dependence of value of statistics of criteria $W(n_{H_l})$ from the parameter $n_ф$, $n_{H_l}$

In this case expediently as a minimum value of statistics criteria ($W_{min}$) is to take on a value which answers the parameter $n_{H_l}$ = *7*. This minimum value of criteria showed a lower limit for a value $B \leq \frac{β}{1-α}$. Thus, for every values of parameter $n_ф$,

$\hat{n}_\varsigma$ it is possible to find the value of the parameter $(n_{H_l})_l$ which determine the maximal ($W_{max}$) and the minimum ($W_{min}$) values of A and B [3,5-8].

Using of the received values *A* and *B* (maximum values of criteria, which presented of the parameter $n_{H_l}$) it is possible to decide the system of inequalities relatively the critical areas of values of statistics of on the Neyman-Pirson's plausibility criteria α and β:

$$\begin{cases} A \geq \dfrac{1-\beta}{\alpha} \\ B \leq \dfrac{\beta}{1-\alpha} \end{cases} . \qquad (1)$$

Variants of the results of decision of this system of inequalities (1) are presented in a graphic view (Fig. 4) – for $A_1$ and $B_1$ , (Fig. 5) – for $A_1 < A_2$ and $B_1 > B_2$.

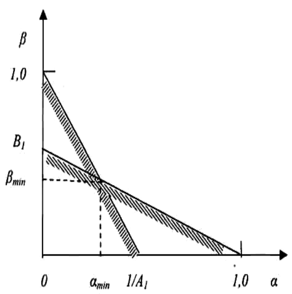


Fig.4. $A_1$ and $B_1$

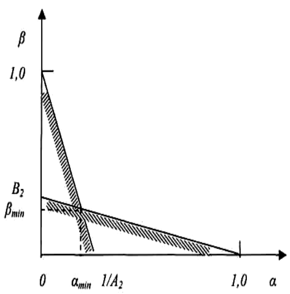


Fig.5. $A_1 < A_2$ , $B_1 > B_2$.

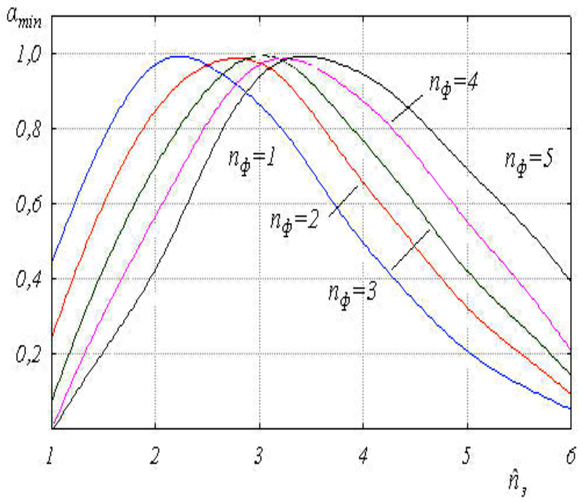


Fig. 6. Graphic of dependences of value $\alpha_{min}$ from the terms of supervisions of parameter $\hat{n}_\varsigma$ at the different values of actual amount of refuses of $n_\phi$

Figures shows, that the every pair of values *A, B* answers the values of $\alpha_{min}$ i $\beta_{min}$. When $A=const$ and $B\downarrow \rightarrow \alpha_{min}\uparrow$, but $\beta_{min}\downarrow$. And vice versa, when $B=const$ and $A\uparrow \rightarrow \alpha_{min}\downarrow$, but $\beta_{min}\uparrow$.

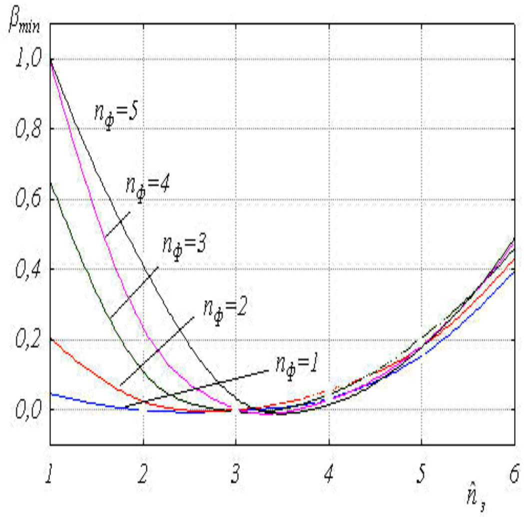


Fig. 7. Graphic of dependences of value $\beta_{min}$ from the terms of supervisions of parameter $\hat{n}_\varsigma$ at the different values of actual amount of refuses of $n_\phi$ .

Graphics of dependences of value $\alpha_{min}$ and $\beta_{min}$ from the terms of supervisions of parameter $\hat{n}_\varsigma$ at the different values of actual amount of refuses of $n_\phi$ are given on the Fig. 6 and Fig. 7.

An example of decision of task of the statistical diagnostic of level of reliability of ship equipment is made [3-5,8].

The basic data are:

$$\hat{\hat{z}}_{з(i+1)j}\ ,\quad \hat{\hat{z}}_{\phi(i+1)j}\ ,\quad n_{\phi(i+1)j}\ ,$$

where: $\hat{\hat{z}}_{з(i+1)j}$ – set value of evaluation of the parameter of stream of refuses of wares for period of exploitation, which is determined from statistical data of previous periods of exploitation ($hours^{-1}$) with application of the improved methodology of statistical evaluation and prognosis of stream refuses parameter taking into account intensity of exploitation;

$n_{\phi(i+1)j}$ – actual amount of refuses of wares founded during period of exploitation at total workload of wares $t_{\Sigma(i+1)}$ .

Implementation of condition $\hat{z}_{з(i+1)j} \geq \hat{z}_{ф(i+1)j}$ is checked up. If a condition is not implement, it is the sign of possible decline of actual level of reliability below set.

The set value of amount of refuses of wares of *j-type* for the $(i+1)$ period of exploitation $\hat{n}_{ς(i+1)j}$, and also the condition of distribution of size $\hat{n}_{ςj}$ is checked up on the cut away normal law.

At implementation of condition of distribution of size on a law verification of truth of hypothesis about the Poisson's parameter of component distribution:

Received parameter $n_{ф(i+1)j}$ =*3*, and certain that parameter $\hat{n}_{ς(i+1)j}$ = 3. In a table 1, in a column which answers $n_{ф}$ = *3* find on the left $\hat{n}_{ς(i+1)j}$ = 3. This value to the Poisson's parameter of component distribution answers the hypothesis of $H_0$ set forth before;

In the column of table 1 for parameter $n_{ф}$ = *3* find on the right a value of parameter $n_{H_1}$ = *4*, that answers $\hat{n}_{ς(i+1)j}$ = *3*. This value of the Poisson's parameter of component distribution answers the hypothesis of $H_1$ set forth before;

Implementation of condition $n_{H_1} > \hat{n}_{ς(i+1)j}$ is checked up. A presence of this condition is the sign of possible decline of actual level of reliability below set.

## 5. Discussion

The proposed method is the methodological basis for search of extremums of Neyman-Pirson's criteria of the supervisions terms and permit to provide the diagnostic of ship onboard equipment reliability.

## 6. Conclusions about research and prospects of further researches herein in this direction

At implementation of condition $n_{H_1} > \hat{n}_{ς(i+1)j}$ it is necessary to check possibility of acceptance of hypothesis of $H_1$ or $H_0$ on the one of variant given below.

Situation $α_{min} < β_{min}$ means the rightness on a hypothesis $H_0$. At the concrete value of parameter $n_{ф}$ for the control period of exploitation, actual level of reliability, which is characterized by a parameter $n_{H_1}$, equals set, that responds to the condition $n_{H_1} = \hat{n}_{ς(i+1)j}$. An acceptance of hypothesis of $H_0$ is a ground for continuation of exploitation of ships equipment checked.

For verification of possibility of acceptance of hypothesis of $H_1$ it is necessary to carry out comparison of minimum values of authenticity of errors of the first level ($α_{min}$) and of the second level ($β_{min}$) (Fig. 2, 3);

Inequality $α_{min} > β_{min}$ shows the rightness of hypothesis of $H_1$. In this case the values $α_{min}$ and $β_{min}$, can run to the border of values: $α_{min} \to 1, 000$, $β_{min} \to 0,000$, that means that with high authenticity the hypothesis of $H_1$ can be accepted.

In case of the defined value of parameter $n_{ф}$ for control period of exploitation and actual level of reliability, which is correspond to a parameter $n_{H_1}$, is below set, that responds to the condition $n_{H_1} > \hat{n}_{ς(i+1)j}$. In this case it is necessary to conduct the analysis of possible reasons of decline of equipment reliability level on results of which take a measures for conduct level of reliability needed (technical maintenance as per instructions and maintenance books, check of certain type equipment, modernization of separate equipment unit or whole complex.)

In accordance with the features of setting of certain type of ship equipment and shipboard systems, and also development of technologies on the maritime and inland water transport, possible reduction to the quantity of crewmembers on ships in the future, the procedure of reliability diagnostic of ships' equipment must be additionally studied and improve in further.

## References

[1] Anderson T. W. (1994) *Statistical Analysis of Time Series*. New York, Wiley-Interscience Publ., 704 p.

[2] Arab-Ogly E.A., Bestuzhev-Lada I.V., Gavrilov N.F. (1982) *Rabochaya kniga po prognozirovaniyu* [Working book on prognostication]. Moscow, "Mysl" Publ., 430 p.

[3] Borovikov V. (2003) *Iskusstvo analiza dannykh na kompyuteri: dlya professionalov* [Art of analysis of data on a computer: for professionals]. Saint-Petersburg, "Statistica" Publ., 688 p.

[4] Gaskarov D.V., Golinkevich T.A., Mozgalevskiy A.V. (1974) *Prognozirovaniye tekhnicheskogo sostoyaniya i nadyozhnosti radioelektronnoy apparatury* [Prognostication of the technical state and reliability of radio electronic equipment]. Moscow, Sovetskoye Radio Publ., 224 p.

[5] Danik O.V. (2017) *Sposib kontrolyu rivnya nadiynosti sudnovykh kompleksiv pri nestabil'nykh umovakh sposterejennya* [A method for controlling the level of reliability marine complex in unstable conditions of observations]. Kiev, *"Naukovy zapysky UNDIZ"*, Issue No. 1 (45), pp. 104-108.

[6] Ivanovich V.V., Il'in O. Yu., Kucheruk S.M. (2013) *Prognozuvannya bezvidmovnosti obladnannya zasobiv vodnogo transportu metodamy statystychnogo analyzu chasovykh ryadiv* [Prognostication of faultlessness of equipment of facilities of water transport objects by the methods of statistical analysis of time series]. Kiev, KSAWT, *"Vodnyy Transport",* Issue No. 2., p. 218-223.

[7] Lavrinenko V.F., Stadnik A.I., Torokhtey V.P. (2014) *Vybor metoda mnogokriterial'noy optimizacii dlya upravleniya vodnym transportnym sredstvom* [Choice of method of multicriterion optimization for a management by a water transport object]. Kiev, KSAWT, *"Vodnyy Trtansport".* Issue No. 3 (21). pp. 11-14.

[8] Tyurin Yu.P., Makarov A.A. (2003) *Analiz dannykh na kompyutere* [Analysis of data on a computer]. Moscow, "Infra-M" Publ., 544 p.

[9] Shumway R. H., Stoffer D. S. (2010) *Time Series Analysis and its Applications. With R Examples. Third edition.* NY, Springer New York Dordrecht Heidelberg London Publ., 576 p. ISBN 978-1-4419-7864-6. DOI 10.1007/978-1-4419-7865-3.

[10] Allianz Global Corporate & Specialty *«Safety and Shipping Review 2015»* Available at: https://www.cesam.org/documents/Shipping-Review-2015.pdf .

[11] Official site of the International Maritime Organization. *Casualties Statistic Analysis* Available at: http://www.imo.org/en/KnowledgeCentre/ShipsAndShippingFactsAndFigures/Statisticalresources//Documents/FSI%2020%20INF-17%20%20Casualty%20statistics%20-%20loss%20of%20life%20from%202006%20to%20date.pdf .

[12] Global Integrated Shipping Information System (GISIS) portal on the official site of site of the International Maritime Organization. *Casualties Statistic* Available at: https://gisis.imo.org/Public/MCI/Default.aspx.

Received 20 December 2017

**І.В. Тихонов**

**Метод статистичного діагностування надійності суднового обладнання**

Державний університет інфраструктури та технологій
вул. Кирилівська, 9, Київ, 04071, Україна
E-mail: itykhonov@i.ua

**Мета:** метою цієї статті є представлення методу статистичного діагностування надійності суднового бортового електронного обладнання, що використовує імовірнісну модель потоку відмов за критеріями правдоподібності Неймана-Пірсона. **Метод:** стаття описує спосіб урахування цих критеріїв, які дозволяють підвищити рівень контролю за станом надійності суднового бортового обладнання з використанням статистичного діагностування. **Результат:** на підставі отриманих аналізів відносно ступеню надійності суднового обладнання приймається рішення щодо можливого зниження фактичного рівня надійності нижче заданого рівня термінів та обсягу його технічного обслуговування. **Дискусія**: запропонований метод є методологічною базою для пошуку екстремумів за критеріями Неймана-Пірсона відносно умов спостереження і дозволяє здійснювати діагностику надійності суднового бортового навігаційного обладнання.

**Ключові слова:** значення параметру; статистичне діагностування; суднове електронне обладнання; технічне обслуговування.

**И.В. Тихонов**

**Метод статистического діагностирования надежности судового оборудования**

Государственный университет инфраструктуры и технологий
ул. Кирилловская9, Киев, 04071, Украина
E-mail: itykhonov@i.ua

**Цель:** целью этой статьи является представление метода статистического диагностирования надежности судового бортового электронного оборудования, при котором используется вероятностная модель потока отказов по критерию правдоподобности Неймана-Пирсона. **Метод:** статья описывает способ учета этих критериев, которые позволяют повысить уровень контроля за состоянием надежности судового оборудования с использованием статистического диагностирования. Результат: На основании полученных результатов относительно степени надежности судового оборудования принимается решение относительно возможного снижения фактического уровня надежности ниже заданного уровня, а также сроками та объема его технического обслуживания. **Дискуссия:** предложенный метод является методологической базой для поиска экстремумов за критериями Неймана-Пирсона относительно условий наблюдения и позволяет осуществить диагностику надежности судового бортового навигационного оборудования.

**Ключевые слова:** значение параметра; статистическое диагностирование; судовое электронное оборудование; техническое обслуживание.

**Tykhonov Illya (**1963).
Candidate of Technical Science (PhD)
Docent (Professors' Assistant)
Department of Navigation and Ships' Management, State University of Infrastructure and Technologies
Education: Odessa Higher Engineering Marine School, Ukraine (1989).
Field of research: Technical science
Publications: 40.
E-mail: itykhonov@i.ua