UDC 656.62 **DOI: 10.33082/td.2019.2-5.01**

RISK-ORIENTED SAFETY MANAGEMENT STRATEGY ON INLAND WATERWAYS OF UKRAINE

A.V. Shakhov[1], O.I. Rossomakha[2], O.I. Sherstyuk[3], O.A. Rossomakha[4]

[1] DSc, Vice-rector,
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0003-0142-7594, avshakhov@ukr.net
[2] Assistant of the Department «Ship maintenance and repair»,
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0002-4425-2192, eirossomakha@gmail.com
[3] PhD, Senior Lecturer of the Department «Professional English»,
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0002-0482-2656, olusha972@gmail.com
[4] Senior Lecturer of the Department "Marine Power Plants and Technical Operation",
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0002-0230-9453, roleg.post@gmail.com

Abstract

Introduction. *Over the past 20 years, the cargo flow by river in Ukraine has a 6–7 times decrease, although the volume of traffic has recently tended to increase. According to the results of 2018, it amounted to only 10 million tons, and passenger traffic was reduced to almost zero. It is known that the traditional approach to safety is based on the categorical imperative: to ensure "absolute" safety and to prevent any accidents. As practice shows, such a concept is not adequate to the real situation. The modern world rejected the concept of "absolute" safety, in view of the impossibility of achieving it, and came up with the concept of acceptable (admissible) risk. Large financial resources spent on improving the safety of technical systems reduce the amount of funds allocated for the purchase of personal protective equipment, medical care, wages, etc. In this case, the social sphere of production can be significantly damaged. Safety of inland navigation can be defined as the property to implement production processes without consequences, and in case of emergencies to be able to restore the parameters or normal functioning of production processes carried out at this facility.* ***Purpose.*** *The aim of the research is to develop the theoretical foundations of the safety navigation management strategy on inland waterways based on the concept of acceptable risk.* ***Results.*** *In [6], the model of the safety management process for the production processes of inland navigation is proposed, the conceptual difference of which from the traditional one is the joint participation of all stakeholders in the management at all project phases. The condition for the project initiation should be considered as the condition under which the project budget is less than reducing the risk of an emergency as a result of the implementation of this project. The overall mission of such a program can be formulated as follows: ensuring the use of such a level of experts in safety, the use of such organizational and technological schemes, such a state of*

inland navigation infrastructure facilities, in which the risk of an emergency as a result of any technological process does not exceed an acceptable level. It is known that there are three classification methods: hierarchical, facet and descriptor [34]. Obviously, due to the specifics of the problem being solved, the facet method is of the greatest value. The facet classification method assumes that the initial set of objects is divided into subsets of groupings according to the classification criteria, that is, facets, which are independent of each other. A facet is a set of values for an individual classification criterion; all facets are mutually independent. ***Conclusions.*** *The peculiarity of the proposed model is that it simultaneously initiates and implements many safety projects. Therefore, a portfolio of projects for ensuring the inland navigation infrastructure safety, that is, a set of projects or programs combined together to effectively manage them, achieve goals and fulfill safety requirements, should be considered. This portfolio should be continuously reviewed and constantly re-planned at various decision-making levels. Decision-making on the expediency of including a group of projects in the portfolio is carried out at the stage of project re-evaluation and if the corresponding decision is made, then the next selection of projects for ranking is initiated.*

Key words: *waterways, navigation safety management, acceptable risk, faceted risk assessment method.*

УДК 656.62

РИЗИКО-ОРІЄНТОВНА СТРАТЕГІЯ УПРАВЛІННЯ БЕЗПЕКОЮ СУДНОПЛАВСТВА НА ВНУТРІШНІХ ВОДНИХ ШЛЯХАХ УКРАЇНИ

А.В. Шахов[1], О.І. Россомаха[2], О.І. Шерстюк[3], О.А. Россомаха[4]

[1] д.т.н., проректор,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0003-0142-7594, avshakhov@ukr.net
[2] асистент кафедри «Технічне обслуговування і ремонт суден»,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0002-4425-2192, eirossomakha@gmail.com
[3] к.т.н., старший викладач кафедри «Професійна англійська мова»,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0002-0482-2656, olusha972@gmail.com
[4] старший викладач кафедри «Суднові енергетичні установки та технічна експлуатація»,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0002-0230-9453, roleg.post@gmail.com

Анотація

Введення. *За минулі 20 років вантажопотік річковим транспортом в Україні скоротився в 6-7 разів, хоча обсяг перевезень останнім часом має тенденцію до зростання. За результатами 2018 року він склав всього 10 млн тон, а пасажирські перевезення зведені майже до нуля. Відомо, що традиційний підхід до безпеки базується на категоричному імперативі: забезпечити «абсолютну» безпеку, не допустити ніяких аварій. Як показує практика, така концепція не адекватна реальній ситуації. Сучасний світ відкинув концепцію «абсолютної»* *безпеки, зважаючи на неможливість її досягнення, і прийшов до концепції прийнятного (допустимого) ризику. Великі фінансові кошти, що витрачаються на підвищення безпеки технічних систем, зменшують кількість коштів, що виділяються на придбання засобів індивідуального захисту, медичне обслуговування, заробітну плату і т.д. В цьому випадку соціальній сфері виробництва може бути завдано значної шкоди. Безпеку внутрішнього судноплавства можна визначити, як властивість реалізовувати виробничі процеси без наслідків, а при виникненні аварійних ситуацій мати можливість відновлювати параметри або нормальне функціонування виробничих процесів, здійснюваних на цьому об'єкті.* ***Мета.*** *Метою дослідження є розробка теоретичних основ стратегії управління безпекою судноплавства на внутрішніх водних шляхах на основі концепції прийнятного ризику.* ***Результати.*** *В роботі [6] пропонується модель процесу управління безпекою виробничими процесами внутрішнього судноплавства, концептуальну відмінність якої від традиційної полягає в спільній участі в управлінні на всіх фазах проекту всіх зацікавлених сторін. Умовою ініціації того чи іншого проекту слід вважати умову, за яким бюджет проекту виявляється менше, ніж зменшення ризику виникнення аварійної ситуації в результаті реалізації даного проекту. Загальну місію такої програми можна сформулювати наступним чином: забезпечення використання такого рівня фахівців з безпеки, використання таких організаційно-технологічних схем, такого стану об'єктів інфраструктури внутрішнього судноплавства, при якому ризик виникнення аварійної ситуації в результаті реалізації будь-якого технологічного процесу не перевищує прийнятного рівня. Відомо, що розрізняють три методи класифікації: ієрархічний, фасетний та дескрипторний. Очевидно, що в силу специфіки розв'язуваної задачі найбільшу цінність для нас представляє саме фасетний метод. Фасетний метод класифікації передбачає, що вихідна безліч об'єктів розбивається на підмножини груп з незалежними між собою ознаками класифікації – фасетами. Фасет – набір значень окремого ознаки класифікації, все фасети взаємно незалежні.* ***Висновки.*** *Особливість пропонованої моделі полягає в тому, що в ній одночасно ініціюються і реалізуються безліч проектів забезпечення безпеки. Тому, слід говорити про портфелі проектів забезпечення безпеки інфраструктури внутрішнього судноплавства – наборі проектів або програм, об'єднаних разом з метою їх ефективного управління для досягнення цілей і виконання вимог з безпеки. Цей портфель повинен безперервно аналізуватися і постійно піддаватися перепланування на різних рівнях прийняття рішень. Ухвалення рішення про доцільність включення групи проектів в портфель здійснюється на етапі переоцінки проектів і якщо відповідне рішення прийнято, то ініціюється черговий відбір проектів для ранжирування.*

Ключові слова: *водні шляхи, управління безпекою судноплавства, прийнятний ризик, фасетний метод класифікації ризику.*

УДК 656.62

РИСКО-ОРИЕНТИРОВАННАЯ СТРАТЕГИЯ УПРАВЛЕНИЯ БЕЗОПАСНОСТЬЮ СУДОХОДСТВА НА ВНУТРЕННИХ ВОДНЫХ ПУТЯХ УКРАИНЫ

А.В. Шахов[1], О.И. Россомаха[2], О.И. Шерстюк[3], О.А. Россомаха[4]

[1] д.т.н., проректор,
Одесский национальный морской университет, Одесса, Украина,
ORCID ID: 0000-0003-0142-7594, avshakhov@ukr.net
[2] ассистент кафедры «Техническое обслуживание и ремонт судов»,
Одесский национальный морской университет, Одесса, Украина,
ORCID ID: 0000-0002-4425-2192, eirossomakha@gmail.com
[3] к.т.н., старший преподаватель кафедры «Профессиональный английский язык»,
Одесский национальный морской университет, Одесса, Украина,
ORCID ID: 0000-0002-0482-2656, olusha972@gmail.com
[4] старший преподаватель кафедры
«Судовые энергетические установки и техническая эксплуатация»,
Одесский национальный морской университет, Одесса, Украина,
ORCID ID: 0000-0002-0230-9453, roleg.post@gmail.com

Аннотация

Введение. *За прошедшие 20 лет грузопоток речным транспортом в Украине сократился в 6–7 раз, хотя объем перевозок в последнее время имеет тенденцию к росту. По результатам 2018 года он составил всего 10 млн тонн, а пассажирские перевозки сведены почти к нулю. Известно, что традиционный подход к безопасности базируется на категорическом императиве: обеспечить «абсолютную» безопасность, не допустить никаких аварий. Как показывает практика, такая концепция не адекватна реальной ситуации. Современный мир отверг концепцию «абсолютной» безопасности, ввиду невозможности ее достижения, и пришел к концепции приемлемого (допустимого) риска. Большие финансовые средства, затрачиваемые на повышение безопасности технических систем, уменьшают количество средств, выделяемых на приобретение средств индивидуальной защиты, медицинское обслуживание, заработную плату и т.д. В этом случае социальной сфере производства может быть нанесен значительный ущерб. Безопасность внутреннего судоходства можно определить, как свойство реализовывать производственные процессы без последствий, а при возникновении аварийных ситуаций иметь возможность восстанавливать параметры или нормальное функционирование производственных процессов, осуществляемых на этом объекте.* ***Цель.*** *Целью исследования является разработка теоретических основ стратегии управления безопасностью судоходства на внутренних водных путях на основе концепции приемлемого риска.* ***Результаты.*** *В работе [6] предлагается модель процесса управления безопасностью производственными процессами внутреннего судоходства, концептуальное отличие которой от традиционной состоит в совместном участии в управлении на всех фазах проекта всех заинтересованных сторон. Условием инициации того или иного проекта следует считать условие, по которому бюджет проекта оказывается меньше, чем* *уменьшение риска возникновения аварийной ситуации в результате реализации данного проекта. Общую миссию такой программы можно сформулировать следующим образом: обеспечение использования такого уровня специалистов по безопасности, использование таких организационно-технологических схем, такого состояния объектов инфраструктуры внутреннего судоходства, при котором риск возникновения аварийной ситуации в результате реализации любого технологического процесса не превышает приемлемого уровня. Известно, что различают три метода классификации: иерархический, фасетный, дескрипторный. Очевидно, что в силу специфики решаемой задачи наибольшую ценность для нас представляет фасетный метод. Фасетный метод классификации предполагает, что исходное множество объектов разбивается на подмножества группировок по независимым между собой признакам классификации – фасетам. Фасет – набор значений отдельного признака классификации, все фасеты взаимно независимы.* ***Результаты.*** *Особенность предлагаемой модели заключается в том, что в ней одновременно инициируются и реализуются множество проектов обеспечения безопасности. Поэтому, следует говорить о портфеле проектов обеспечения безопасности инфраструктуры внутреннего судоходства – наборе проектов или программ, объединенных вместе с целью их эффективного управления для достижения целей и выполнения требований по безопасности. Этот портфель должен непрерывно анализироваться и постоянно подвергаться перепланированию на различных уровнях принятия решений. Принятие решения о целесообразности включения группы проектов в портфель осуществляется на этапе переоценки проектов и если соответствующее решение принято, то инициируется очередной отбор проектов для ранжирования.*

Ключевые слова: *водные пути, управления безопасностью судоходства, приемлемый риск, фасетный метод оценки риска.*

Problem statement

The accelerated economic development of the state, as international experience shows, is impossible without the advanced development of transport infrastructure. One of the ways to solve this problem in Ukraine, according to many domestic and foreign experts, is the revival of shipping by inland waterways. In this approach, there are both positive and negative sides.

The only economic feasibility of this solution is beyond doubt. However, for the water environment, any vessel is a source of negative impact, taking this ecosystem out of equilibrium. During the operation of the fleet in the water environment and in the atmosphere, in any case, organic or inorganic residues are emitted, exhaust gases from the operation of the main engines, diesel generators, boiler plants have noise, vibration that are unusual for the optimal state of water displacement, which together cause irreparable damage to its biological resources, flora and fauna. It results in changes in the water area power engineering, which cannot but affect the dynamics of stream flows.

Over the past 20 years, the cargo flow by river in Ukraine has a 6–7 times decrease, although the volume of traffic has recently tended to increase. According to the results of 2018, it amounted to only 10 million tons, and passenger traffic was reduced to almost zero [21].

As a result of such a recession and confirmed underfunding of the inland water transport infrastructure, the cascade of reservoirs on the Dnieper was on the verge of a man-made disaster. Currently, 85% of the infrastructure of shipping locks is worn out, and 90% of inland navigation vessels are morally and physically obsolete. If the locks are not restored in 2019–2020, the risk of environmental disaster increases significantly. This conclusion was made by engineers of the US Army Corps, who examined the Dnieper River locks in 2016 [21].

Thus, a prerequisite for the development of inland navigation is the development and implementation of a science-based strategy for managing safety of river transport. As a methodological basis of such a strategy, the risk theory, models and methods for managing projects, programs and project portfolios, and mechanisms of public-private partnerships can be used.

Literature review

It is known that the traditional approach to safety is based on the categorical imperative: to ensure "absolute" safety and to prevent any accidents. As practice shows, such a concept is not adequate to the real situation. The modern world rejected the concept of "absolute" safety, in view of the impossibility of its achievement, and came up with the concept of acceptable (admissible) risk [27-29].

The need to formulate the concept of acceptable risk as a safety level for the production processes of inland navigation is due to the impossibility of creating absolutely safe technological processes and trouble-free equipment and systems. The amount of acceptable risk should combine technical, economic and social aspects of the activity. In practice, this is always a compromise between the achieved level of safety and the possibilities of increasing it by economic, technological, organizational and other methods. However, the economic possibilities for improving safety of technical and sociotechnical systems are not unlimited. Large financial resources spent on improving safety of technical systems reduce the amount of funds allocated for the purchase of personal protective equipment, medical care, wages, etc. In this case, the social sphere of production can be significantly damaged.

Acceptable (admissible) risk of an emergency R_{acc} is defined as the maximum amount of risk that is appropriate for technical, economic and technological capabilities for this production process. Acceptable risk can be considered as a compromise between the safety level and the possibilities of achieving it [30].

Acceptable risk criteria are usually based on operational, technical, economic, regulatory, social or environmental factors, or a combination thereof. The basic principles of risk acceptance (ALARP, MEM, GAMAB) are considered in [31-33].

Safety of any object participating in the inland navigation process depends on the condition of facilities (ships, ports, channels) and on the hazards arising during operation. Given the significant differences between the elements of the system, as well as the existence of different goals for the subjects of the transportation process, a different meaning can be put into the concept of safety. Common definitions and safety assessment criteria are for today. Both safety of facilities and safety of people, cargo safety, environmental safety, etc. are considered in an equivalent manner.

Summarizing the points of view of various authors [27-29], safety of inland navigation can be defined as the property to implement production processes without consequences, and in case of emergencies be able to restore the parameters or normal functioning of production processes carried out at this facility.

Safety of production activities on inland waterways is ensured by safety of floating crafts, port infrastructure facilities, people, cargo, environment, as well as safety of the main, auxiliary and servicing processes.

Apparently, the results of such activities have a large number of stakeholders: shipping companies, ports, cargo owners, state authorities and local governments. Moreover, their goals often do not coincide, which leads to conflicts of interest that reduce the overall efficiency of the processes. In recent decades, the solution to this problem has been found in the use of project, portfolio and program management methodologies [32-34].

The aim of the research is to develop the theoretical foundations of the safety navigation management strategy on inland waterways based on the concept of acceptable risk.

The main research material

Of the large number of risk definitions, the most common, in our opinion, is the definition from the ISO 31000 standard [3]: "Risk is the effect of uncertainty on goals." From this formulation, the following main signs of risk can be distinguished.

Firstly, risks arise only when performing any targeted actions. If the purpose of your organization is not trade and economic operations with any state, then the condition of the financial system of this country is insignificant for you. Based on this postulate, the adoption of the law on compulsory health insurance cannot be considered as risk for a shipping company or river port, although these events will have some impact on organizations (additional costs for insurance of their employees will be borne by enterprises). Such an impact must lead to the reconsideration of the organization’s goals and the projects it implements.

Secondly, an event that has clearly defined causes and negative consequences should be considered as risk. Therefore, such frequently occurring terms as environmental risk, credit risk, production risk, etc. should be considered incorrect. Such characteristics can be used as the basis for classification, but not risks of a particular organization.

Thirdly, risk is an event that can occur only with any probability other than zero and one. Therefore, one of the main parameters assessing risk is the probability of occurrence of this event.

Fourthly, any risk should be considered as an economic category. Therefore, in a quantitative assessment, the risk (R) is numerically equal to the product of the probability of occurrence of the risk event (P) and the damage (U) that will be caused to the organization if this event occurs:

$$R = P \cdot U.$$

And finally, fifthly, if we compare the presented definition of risk and the classical definition of a project according to the PMBOK standard (a project is a temporary organization created to achieve specific unique goals), it becomes obvious that risk management is the main tool for managing projects, programs and portfolios. Not by chance, that this function has been given much attention in recent years in a number of publications devoted to improving the project management methodology [4].

In [6], the model of the safety management process for the production processes of inland navigation is proposed, the conceptual difference of which from the traditional one is the joint participation of all stakeholders in the management at all project phases.

Recently, in most countries of the world community, the concept of ALARA, as low as risk acceptable, allowing the use of the "foresee and warn" principle has been adopted for risk management, and, consequently, ultimately, safety.

Therefore, one of the basic principles of managing safety of navigation infrastructure on inland waterways, incorporated into the proposed model, is the principle of proactive management [31]. It is known that the difference between the classical (reactive) principle of management and proactive management is as follows. The purpose of the first one is to respond to incidents and prevent their recurrence, and the second one is to foresee and prevent their occurrence. With regard to shipping safety management, this principle means:

1. Proactive management of the current safety state.
2. Prediction and assessment of the future safety state of the system, taking into account its development.

The second basic principle laid down in the proposed model is the use of the program-targeted approach. According to the generally accepted definition, a program is an organic combination of a group of interconnected projects and processes aimed at achieving the overall mission of the program, which is profiled into a tuple of stated goals [34]. Thus, the program will include monitoring and control of the safety level state on ships, shipping lanes, in the territories and water areas of river ports. In addition, the program also contains groups of technical and organizational projects aimed at improving the safety level.

The condition for the project initiation should be considered as the condition under which the project budget is less than reducing the risk of an emergency as a result of the implementation of this project.

The overall mission of such a program can be formulated as follows: ensuring the use of such a level safety experts, the use of such organizational and technological schemes, such a state of inland navigation infrastructure, in which the risk of an emergency as a result of any technological process does not exceed an acceptable level [29].

The proposed model of the safety management process for inland navigation processes includes 6 stages and is presented in Figure 1.

A project for ensuring safety of inland navigation infrastructure is considered as a project that includes a set of organizational and technical measures aimed at reducing quantitative assessments of risks of accidents at facilities and reducing the impact of their consequences. This concept is fully consistent with the basic logical rules for the definition of concepts [24].

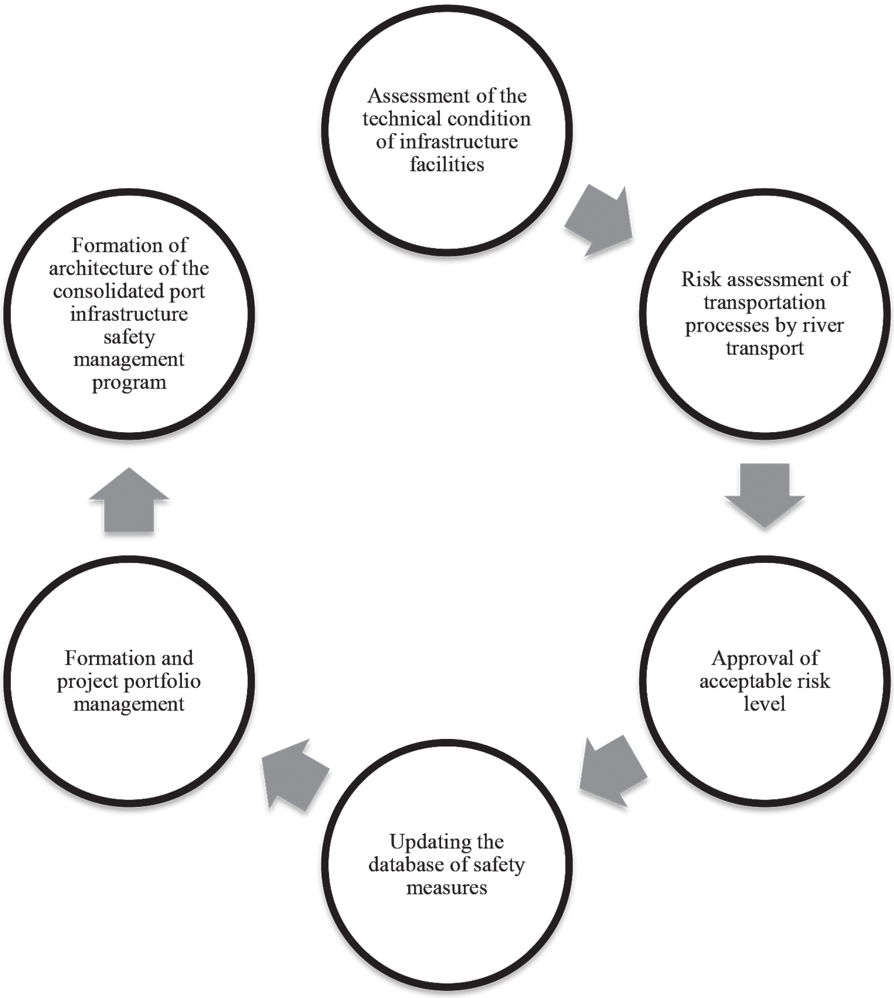

Fig. 1. Model of port infrastructure safety management process.
Source: Author's own development.

A safety project has the following characteristics similar to any other project [25]:

– the goal must be achieved while fulfilling all technical and environmental standards;

– specific deadlines (start and close);

– established financial, material, informational and labor resources (allocated resources);

Differences of this type of project from others are expressed in the following:

– the objective function of the project is not related to the profit received as a result of the project;

– clear focus – all safety projects, without exception, are aimed at protecting personnel, the environment or property;

– the specifics of monitoring the results of projects by government and the public, which determines the need for organizing information support of complex projects with coverage of the project in the press and on television.

The fundamental work on the classification of projects is the work of R. Archibald [25], in which the concept of an integral global system for categorizing projects is proposed. At the same time, the author points out, referring to L. Crawford, that the classification should be carried out exclusively with a focus on practical activities other than theoretical ones.

It is known that there are three classification methods: hierarchical, facet, descriptor [26]. Obviously, due to the specifics of the problem being solved, the facet method is of the greatest value [12]. The determining factors in its choice are the advantages of this method, that is, the flexibility of the system, which determines the ease of use and the possibility of limiting the number of criteria, as well as efficiency in organizing machine processing of data in databases and high-level query languages. The disadvantage of the facet method is the inability to highlight the commonality and differences between objects in different classification groups (as opposed to the hierarchical method). Another feature of the method is the information redundancy of groupings, which in some cases are impossible in meaning. However, these weaknesses of the method can be leveled by analytical work aimed at finding and selection of combinations of criterion values inherent in frequency projects.

The facet classification method assumes that the initial set of objects is divided into subsets of groupings according to the classification criteria, that is, facets, which are independent of each other. A facet is a set of values for an individual classification criterion; all facets are mutually independent.

Each object simultaneously has classification criteria from various ones by setting a facet formula, that is, a sequence of facets and values of the classification criteria of the selected facets.

Classifier K of projects for ensuring the port infrastructure safety level is described by a tuple:

$$K = \langle F, V \rangle , \quad (1)$$

where F – a set of classifier facets, V – a set of project classification criteria,

$$F = \{ f_i \} , \quad (2)$$

where f_i – i-th facet, $i = 1 \ldots n$, n – cardinality of the set of facets F,

$$V = \{ v_{ij} \} , \quad (3)$$

where v_{ij} – j-th classification criteria of the i-th facet, $j = 1 \ldots m_i$, m_i – cardinality of the set of classification criteria of the i-th facet. It should be noted what is a set, because, in fact, it defines the interval of the criteria change inherent in the project class.

For facets, the uniqueness condition is fulfilled:

$$\begin{cases} \bigcup_{i=1}^{n} f_i = F \\ \bigcap_{i=1}^{n} f_i = \varnothing \end{cases}. \tag{4}$$

For classification criteria, the condition of uniqueness within the facet is also necessarily fulfilled:

$$\begin{cases} \bigcup_{i=1}^{n} v_{ij} = V_i \\ \bigcap_{i=1}^{n} v_j = \varnothing \end{cases}. \tag{5}$$

where V_i – a set of classification criteria of the *i*-th facet.

The maximum capacity *M* of the classifier is defined as the power of the set *G* of possible classification groups according to the formula:

$$M = \prod_{i=1}^{n} |\{V_i\}|. \tag{6}$$

Generation of elements g_k of the set *G* of classification groups

$G = \{g_k\},$ где $k = 1...M$

takes place in accordance with the following rule:

$$g_k = \left\{ (f_i, v_j) \mid \forall f_i \left(\left(\bigcup_{i=1}^{n} f_i = F \right) \wedge \left(v_j \in V_i \right) \wedge |g_k| = |F| \right) \right\}. \tag{7}$$

Based on the assumption that any project can be described by the expression

$$p_q = \{(f_i, r_{iq})\},$$

where p_q – a project belonging to the set of the current portfolio of projects, r_{iq} – the value of the characteristic of the *q*-th project to the *i*-th facet, the definition of the project's belonging to a certain classification group – its classification, occurs in accordance with the following rule:

$$\forall p_q \left(\exists g_k \left(\forall r_{iq} \left(r_{iq} \in V \rightarrow И \right) \right) \right) \tag{8}$$

Expressions (1-8) allow developing algorithmic and software for classifying projects to ensure the port infrastructure safety level, which, in turn, is the basis of the decision support system for the project portfolio manager.

The peculiarity of the proposed model is that it simultaneously initiates and implements many safety projects. Therefore, a portfolio of projects for ensuring the inland navigation infrastructure safety, that is, a set of projects or programs combined together to effectively manage them, achieve goals and fulfill safety requirements, should be considered. This portfolio should be continuously reviewed and constantly re-planned at various decision-making levels.

From the perspective of the general theory of systems [34], a generalized (holistic) model of portfolio management processes for port infrastructure projects can be considered in two ways. On the one hand, this is a holistic object S_1 implementing a control function (external description). Moreover, the control function is implied as the successful implementation of the initiated measures *X* into the set *Y* of results (values) aimed at improving safety, which is described by the ratio

$$S_i = X \in Y . \tag{9}$$

The set *X* is formed by the inputs of the system (hereinafter, the system is understood as an integrated complex of software, hardware, human and other resources that implements the control function), and the set *Y* by the outputs, as the implementation of the goals of its functioning. In particular, decisions on project initiation, data on projects and the state of port infrastructure facilities, information on financial status, etc. form the system inputs, while decisions on completion of projects, port infrastructure facilities characterized by a lower risk of accidents, recommendations for increasing the effectiveness of management processes form its outputs.

Combining the inputs and outputs of the system into one set V_i, called the system object [31], it is obtained:

$$X = \times\{V_i : i \in I_x\}, Y = \times\{V_i : i \in I_y\}, \tag{10}$$

where the sets I_x and I_y form the partition of the set of indices I , i.e.

$$I_x \cap I_y = \varnothing \wedge I_x \cup I_y = I . \tag{11}$$

Then the expression describing the system will take the form:

$$S_1 \subset V_1 \times V_2 \times \ldots \times V_m . \tag{12}$$

On the other hand, the project portfolio management system is a process model consisting of the set of managerial stages, that is, certain sets of actions, as a result of which some managerial decision is made [23-26]. This set S_2, characterized by the presence of a structure due to the features of the life cycles of project management processes, is an internal description of the system:

$$S_2 \subset C_1 \times C_2 \times \ldots \times C_n , \tag{13}$$

where *n* – number of management structures.

Examples of management phases are analysis and evaluation of projects, classification of projects, ranking of projects in a portfolio, evaluation of project performance, etc.

Thus, the holistic description of the port infrastructure safety portfolio management system S takes the form

$$S = \begin{cases} S_1 \subset V_1 \times V_2 \times \ldots \times V_m \\ S_2 \subset C_1 \times C_2 \times \ldots \times C_n \end{cases}. \qquad (14)$$

A feature of managing a portfolio of safety projects is that during the planning period, some projects are completed and, accordingly, removed from the portfolio, other projects from the total number of planned projects are added to the portfolio. A prerequisite for effective work to improve safety of port infrastructure is the possibility of preliminary selection of projects by experts. In accordance with the proposed management model, "compulsory" projects are placed in the project portfolio first (without the implementation of which the operation of inland waterways is impossible, and then the proposed projects are classified and ranked. After that, the success of the portfolio as a whole is assessed. If the assessment is positive and selection of many projects is carried out, the current portfolio is formed and its composition is approved.

If the experts are not satisfied with the preliminary ranking results and comprehensive portfolio performance assessment, there is a possibility of returning and re-selecting projects for analysis and inclusion in the portfolio. The implementation of projects in the portfolio is subject to constant monitoring and control. As they are completed, a part of the resources is released and the next block of projects can be included in the portfolio. Decision-making on the expediency of including the next group of projects in the portfolio is carried out at the stage of project re-evaluation and if the corresponding decision is made, then the next selection of projects for ranking is initiated.

Conclusions

1. The relevance of the concept of managing the state of inland waterway transportation safety is due, first of all, to the contradictions that arise in the process of development of this type of transport. The main contradiction is an increase in the production potential of the infrastructure, which is associated with the development of production forces, and, consequently, an increase in the man-caused load, on the one hand, and the need to preserve the environment and safe operation of facilities, on the other.

2. Possible risks of production processes should be below the level of acceptable risks, which are established in advance, based on the general development strategy, including consideration of the expected final economic effect.

3. The conclusion is drawn on the appropriateness of a program-targeted proactive approach to managing the inland water transportation safety, which is based on the need to reduce, first of all, the influence of hazard factors, and, consequently, the likelihood of an emergency, the concept of acceptable risk and the need to implement a large number of projects and portfolios that ensure the achievement of one strategic goal, that is, maintaining and improving safety in terms of resource constraints. The obvious

advantage of this approach is the ability to simultaneously analyze many ongoing projects, which allows the correct allocation of resources between them.

4. An infrastructure safety management model based on a program-targeted and proactive approach has been developed, the choice of the main category concepts, a joint consideration of which is necessary within the proposed concept, has been substantiated.

LITERATURE

1. Тихонов И. В. Методика підвищення ефективності навігаційного забезпечення плавання на внутрішніх водних шляхах. *Вісник НТУУ «КПІ». Серія: радіотехніка, радіоапаратобудування*. 2010. № 40.
2. Егоров Г.В., Егоров А.Г. Исследование надежности и риска эксплуатации отечественных речных круизных пассажирских судов. *Вісник ОНМУ*. 2015. № 1(43). С. 5-32.
3. Каретников В. В., Ефимов К. И., Сикарев А. А. К вопросу оценки рисков на внутреннем водном транспорте Российской Федерации. *Вестник АГТУ. Серия: морская техника и технология*. 2017. № 2.
4. Руководство ISO 73: 2009, Менеджмент рисков. Словарь.
5. IEC 31010:2009, Менеджмент рисков. Методы оценки рисков.
6. Международный стандарт ISO 31000:2018 «Менеджмент риска – руководство.
7. Мустакаева Е. А. Ключевые проблемы функционирования и развития инфраструктуры внутреннего водного транспорта. *Вестник Государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2013. № 1(17).
8. Каретников В. В., Сикарев А. А. Развитие и перспективы современных инфокоммуникационных систем для обеспечения судоходства на внутренних водных путях России. *Вестник Государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2010. № 4(8).
9. Пантина Т. А. Концепция и структурная схема формирования стратегии развития внутреннего водного транспорта Российской Федерации на период до 2030 года. *Вестник государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2011. № 3(11).
10. Ковалёва Е. Н., Водахова В. А. Комплексная оценка качества транспортных услуг, оказываемых на предприятиях внутреннего водного транспорта. *Вестник Государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2015. № 1(29).
11. Черных Н. Н. Перспективы развития грузовых транзитных перевозок внутренним водным транспортом. *Вестник Государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2011. № 4(12).
12. Соляков О. В. Обеспечение безопасного судоходства на внутренних водных путях с использованием навигационной аппаратуры потреби-

теля. *Вестник государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2015. № 1(29).
13. Борисова Н Ф., Скороходов Д.А., Стариченков А.Л. *Интеллектуальные технологии для обеспечения безопасности судоходства*. Транспорт Российской Федерации. 2010. № 1(26).
14. Кацман Ф.М., Ершов А.А. Аварийность морского флота и проблемы безопасности судоходства. Транспорт Российской Федерации. 2006. № 5(5).
15. Бабурин В. А. Современные проблемы организации российского судоходства, экологическая безопасность и качество жизни. *Вестник Государственного университета морского и речного флота им. Адмирала С.О. Макарова*. 2010. № 4(8).
16. Клитина А. Против течения: почему пришел в упадок речной транспорт в Украине. URL: http://www.mind.ua (дата звернення 05.09.2019).
17. Парусная Федерация Харьковской области URL: https://parus.kharkov.ua (дата звернення 05.09.2019).
18. Нычик Т. Ю., Колосов М. А. Управление риском аварий и транспортных происшествий в судоходных шлюзах. *Вестник государственного университета морского и речного флота им. адмирала С.О. Макарова*. 2015. № 5(33).
19. Нычик Т. Ю. Анализ аварийных ситуаций при шлюзовании судов. *Вестник государственного университета морского и речного флота им. адмирала С.О. Макарова*. 2011. № 4(12).
20. ДК 019:2010 "Класифікатор надзвичайних ситуацій".
21. Брушлинский Н.Н., Клепко Е.А. К вопросу о вычислении рисков. *Проблемы безопасности и чрезвычайных ситуаций*. 2004. Вып. 1. С. 71-73.
22. Методы принятия технических решений / Э. Мушик , Ф. Мюллер М.: Мир. 1990.
23. Dunbar J.H. Risk Management and Rick Assesment. *Russian – British Fire Safety and Protection Seminar*. Moscow, 3-5 October 1995.
24. Руденко Е. С. Приемлемый риск как уровень безопасности объектов портовой инфраструктуры. *Проблемы техники*. 2014. № 3. С.88-93
25. МЭК 62278:2002 (IEC 62278:2002) Железные дороги. Технические условия и демонстрация надежности, эксплуатационной готовности, ремонтопригодности и удобства обслуживания (Railway applications-Specification and demonstration of reliability, availability, maintainability and safety (RAMS)).
26. Шебеко Ю.Н., Болодьян И.А., Молчанов В.П. и др. Оценка пожарного риска для берегового перевалочного комплекса аммиака. *Пожарная безопасность*. 2004, № 3. С. 45-51.
27. ГОСТ Р МЭК 61511-3-2011 Безопасность функциональная. Системы безопасности приборные для промышленных процессов. Часть 3. Руководство по определению требуемых уровней полноты безопасности. URL: http://www.docs.cntd.ru/document/1200094220 (дата звернення 10.10.2019).

28. Руденко Е.С. Идентификация и классификация факторов опасности для объектов портовой инфраструктуры. *Вісник* ОНМУ. 2013. № 3(39). С. 233-240.
29. Rudenko E.S., Gogunsky V.D., Chernega Yu.S. Markov model of risk in the life safety projects. Праці Одеського політехнічного університету. 2013. Вип. 2(41). С. 271-276.
30. Руденко Е.С. Ранжирование проектов в программной среде MICROSOFT EXCEL. *Тези доповідей XI міжнародної конференції «Управління проектами у розвитку суспільства»* К.: КНУБА 2014. С. 180-183.
31. Энергетические модели управления проектними организациями / М.О. Бокарева, А.В. Шамов, А.В. Шахов. LAMBERT Academic Publishing, 2015. 192 с.
32. Брушлинский Н.Н., Клепко Е.А. К вопросу о вычислении рисков. *Проблемы безопасности и чрезвычайных ситуаций*. 2004. Вып. 1. С. 71-73.
33. Руденко Е.С., Шахов А.В. Програмно-цільове управління безпекою функціонування морських портів. *Матеріали IX міжнародної науково-практичної конференції «Управління проектами стан та перспективи».* М.: НУК, 2013. С. 278-280.
34. ГОСТ 6.01.1-87 Единая система классификации и кодирования технико-экономической информации. Основные положения. URL: http://vsegost.com/Catalog/46/46344.shtml (дата звернення 01.11.2019).
35. Принятие решений при многих критериях: предпочтения и замещения / Р. Л. Кини, Х. Райфа. М.: Радио и связь, 1981. 560 с.

REFERENCES

1. Tikhonov, I.V. (2010). The methodology of effective performance of navigational safety swimming in internal water hats [Metodika pidvishchennya yefektivností navigatsiynogo zabezpechennya plavannya na vnutrishníkh vodnikh shlyakhakh]. *Visnik NTUU "KPI". Seriya radíotekhnika, radioaparatobuduvannya. 40* [in Ukrainian].
2. Yegorov, G.V., & Yegorov, A.G. (2015). The study of the reliability and risk of operation of domestic river cruise passenger ships [Issledovaniye nadezhnosti i riska ekspluatatsii otechestvennykh rechnykh kruiznykh passazhirskikh sudov]. *Vesnik ONMU. 1 (43)*, 5-32 [in Ukrainian].
3. Karetnikov, V.V., Yefimov, K.I., & Sikarev, A.A. (2017). On the issue of risk assessment in the inland water transport of the Russian Federation [K voprosu otsenki riskov na vnutrennem vodnom transporte Rossiyskoy Federatsii]. *Vestnik AGTU. Seriya: morskaya tekhnika i tekhnologiya. 2* [in Russian].
4. Guide ISO 73: 2009, Risk management. Vocabulary [Rukovodstvo ISO 73: 2009, Menedzhment riskov. Slovar'] [in Russian].
5. IEC 31010: 2009, Risk Management. Risk Assessment Methods

[IEC 31010:2009, Menedzhment riskov. Metody otsenki riskov] [in Russian].
6. International standard ISO 31000: 2018 "Risk management – guidance. [Mezhdunarodnyy standart ISO 31000:2018 «Menedzhment riska – rukovodstvo.] [in Russian]
7. Mustakayeva, Y.A. (2013). Key problems of the functioning and development of the infrastructure of inland water transport [Klyuchevyye problemy funktsionirovaniya i razvitiya infrastruktury vnutrennego vodnogo transporta]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 1(17)* [in Russian].
8. Karetnikov, V.V., & Sikarev, A.A. (2010). Development and prospects of modern infocommunication systems for navigation on the inland waterways of Russia [Razvitiye i perspektivy sovremennykh infokommunikatsionnykh sistem dlya obespecheniya sudokhodstva na vnutrennikh vodnykh putyakh Rossii]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 4(8)* [in Russian].
9. Pantina, T.A. (2011). Concept and block diagram of the formation of a strategy for the development of inland water transport of the Russian Federation for the period until 2030 [Kontseptsiya i strukturnaya skhema formirovaniya strategii razvitiya vnutrennego vodnogo transporta Rossiyskoy Federatsii na period do 2030 goda]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 3(11)* [in Russian].
10. Kovalova, Y.N., & Vodakhova, V.A. (2015). A comprehensive assessment of the quality of transport services provided by inland water transport enterprises [Kompleksnaya otsenka kachestva transportnykh uslug, okazyvayemykh na predpriyatiyakh vnutrennego vodnogo transporta]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 1(29)* [in Russian].
11. Chernykh, N.N. (2011). Prospects for the development of freight transit traffic by inland water transport [Perspektivy razvitiya gruzovykh tranzitnykh perevozok vnutrennim vodnym transportom]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 4(12)* [in Russian].
12. Solyakov, O.V. (2015). Ensuring safe navigation on inland waterways using consumer navigation equipment [Obespecheniye bezopasnogo sudokhodstva na vnutrennikh vodnykh putyakh s ispol'zovaniyem navigatsionnoy apparatury potrebitelya]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 1(29)* [in Russian].
13. Borisova, N.F., Skorokhodov, D.A., & Starichenkov, A.L. (2010). Intelligent technologies for ensuring the safety of navigation [Intellektual'nyye tekhnologii dlya obespecheniya bezopasnosti sudokhodstva]. *Transport Rossiyskoy Federatsii. 1(26)* [in Russian].
14. Katsman, F.M., & Yershov, A.A. (2006). The accident rate of the navy and the problems of shipping safety [Avariynost' morskogo flota i problemy

bezopasnosti sudokhodstva]. *Transport Rossiyskoy Federatsii. 5(5)* [in Russian].

15. Baburin, V.A. (2010). Modern problems of the organization of Russian shipping, environmental safety and quality of life [Sovremennyye problemy organizatsii rossiyskogo sudokhodstva, ekologicheskaya bezopasnost' i kachestvo zhizni]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. Admirala S.O. Makarova. 4(8)* [in Russian].
16. Klitina A. Against the current: why river transport in Ukraine fell into decay [Protiv techeniya: pochemu prishel v upadok rechnoy transport v Ukraine.] [in Russian]. Retrieved from http://www.mind.ua.
17. Sailing Federation of Kharkov region. URL: https://parus.kharkov.ua.
18. Nychik, T.Y., & Kolosov, M.A. (2015). Risk management of accidents and transport accidents in shipping locks [Upravleniye riskom avariy i transportnykh proisshestviy v sudokhodnykh shlyuzakh]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. admirala S.O. Makarova. 5(33)* [in Russian].
19. Nychik, T.Y. (2011). Analysis of emergency situations when ship locks [Analiz avariynykh situatsiy pri shlyuzovanii sudov]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota im. admirala S.O. Makarova. 4(12)* [in Russian].
20. DK 019: 2010 "Classification of suprasubic situations" [DK 019:2010 "Klasifikator nadzvichaynikh situatsiy"] [in Russian].
21. Brushlinskij, N.N., & Klepko, E.A. (2004). On the issue of calculating risks [K voprosu o vychislenii riskov]. *Problemy bezopasnosti i chrezvychajnykh situaczij. 1*, 71-73 [in Russian].
22. Mushik, E., & Myuller, F. Technological decision making methods [Metody priniatiia tekhnicheskikh reshenii]. M.: Mir, 1990 p. [in Russian].
23. Dunbar, J.H. (1995). Risk Management and Rick Assesment. *Russian – British Fire Safety and Protection Seminar*. Moscow.
24. Rudenko, E.S. (2014). Acceptable risk as a security level for port infrastructure facilities [Priemlemy`j risk kak uroven` bezopasnosti ob`ektov portovoj infrastruktury]. *Problemy` tekhniki. 3* [in Russian].
25. IEC 62278:2002 Railway applications-Specification and demonstration of reliability, availability, maintainability and safety (RAMS). [Zhelezny`e dorogi. Tekhnicheskie usloviya i demonstracziya nadezhnosti, e`kspluataczionnoj gotovnosti, remontoprigodnosti i udobstva obsluzhivaniya] [in Russian].
26. Shebeko, Yu.N., Bolod`yan, I.A., & Molchanov, V.P. (2004). Fire risk assessment for the coastal transshipment complex of ammonia [Oczenka pozharnogo riska dlya beregovogo perevalochnogo kompleksa ammiaka]. *Pozharnaya bezopasnost`. 3*, 45-51 [in Russian].
27. GOST R IEC 61511-3-2011 Functional safety. Safety instrumented systems for industrial processes. Part 3. Guidance on determining the required levels of safety integrity [Bezopasnost` funkczional`naya. Sistemy` bezopasnosti priborny`e dlya promy`shlenny`kh proczessov. Chast` 3. Rukovodstvo po

opredeleniyu trebuemy`kh urovnej polnoty` bezopasnosti]. Retrived from: www. http://docs.cntd.ru/document/1200094220 [in Russian].

28. Rudenko, E.S. (2013). Identification and classification of hazard factors for port infrastructure facilities [Identifikacziya i klassifikacziya faktorov opasnosti dlya ob`ektov portovoj infrastruktury`]. *Vestnik ONMU. 3(39)*, 233-240 [in Russian].
29. Rudenko, E.S., Gogunsky, V.D., & Chernega, Yu.S. (2013). Markov model of risk in the life safety projects []. *Pratci Odeskogo politekhnichnogo universitetu. 2(41)*, 271-276.
30. Rudenko, E.S. (2014). Ranking of projects in the MICROSOFT EXCEL software environment [Ranzhirovanie proektov v programmnoj srede MICROSOFT EXCEL]. *Tezi dopovi`dej Kh1 mi`zhnarodnoyi konferenczi`yi «Upravli`nnya proektami u rozvitku suspi`l`stva» K.: KNUBA. 180-183* [in Russian].
31. Bokareva, M.O., Shamov, A.V., & Shakhov, A.V. *Energy models of project organization management* [E`nergeticheskie modeli upravleniya proektnimi organizacziyami]. LAMBERT Academic Publishing, 2015. 192 p. [in Russian].
32. Brushlinskii, N.N., & Klepko, E.A. (2004). On the issue of calculating risks [K voprosu o vychislenii riskov]. *Problemy bezopasnosti i chrezvychainykh situatcii. 1*, 71-73 [in Russian].
33. Rudenko, E.S., & Shakhov, A.V. (2013). Program and management of secure functions of marine ports [Programno-czi`l`ove upravli`nnya bezpekoyu funkczi`onuvannya mors`kikh porti`v]. *Materi`ali IX mi`zhnarodnoyi naukovo-praktichnoyi konferenczi`yi «Upravli`nnya proektami stan ta perspektivi» M.: NUK*, 278-280 [in Russian].
34. GOST 6.01.1-87 Unified system for the classification and coding of technical and economic information. The main provisions. [Edinaya sistema klassifikaczii i kodirovaniya tekhniko-e`konomicheskoj informaczii. Osnovny`e polozheniya]. Retrived from: http://vsegost.com/Catalog/46/46344.shtml [in Russian].
35. Kini, R.L., & Rajfa, Kh. *Decision making under many criteria: preferences and substitutions* [Prinyatie reshenij pri mnogikh kriteriyakh: predpochteniya i zameshheniya]. M.: Radio i svyaz`, 1981. 560 p. [in Russian].