Проведений аналіз проблем безпеки життєдіяльності на об'єктах з масовим перебуванням людей (ОМПЛ). Запропоновано модель-схему загроз при управлінні проектами створення ОМПЛ. Запропоновано використання та описано принципи ідентифікації загроз ОМПЛ на стадії планування. Запропоновано класифікації складних систем в управлінні проектами та програмами системи цивільного захисту. Здійснено порівняльний аналіз методів та алгоритмів щодо використання імітаційного моделювання у проектах даного типу

Ключові слова: управління проектами, імітаційне моделювання, безпеко-орієнтоване управління, об'єкт з масовим перебуванням людей

Проведен анализ проблем безопасности жизнедеятельности на объектах с массовым пребыванием людей (ОМПЛ). Предложена модель-схема угроз при управлении проектами создания ОМПЛ. Предложено использование и описаны принципы идентификации угроз ОМПЛ на стадии планирования. Предложена классификация сложных систем в управлении проектами и программами системы гражданской защиты. Осуществлен сравнительный анализ методов и алгоритмов по использованию имитационного моделирования в проектах данного типа

Ключевые слова: управление проектами, имитационное моделирование, безопасно-ориентированное управление, объект с массовым пребыванием людей

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DEVELOPMENT OF A SIMULATION MODEL OF SAFETY MANAGEMENT IN THE PROJECTS FOR CREATING SITES WITH MASS GATHERING OF PEOPLE

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1. Introduction

Economic, political and social instability of present time stimulates the level of increase in the occurrence of emergencies, including the sites of mass gathering of people (SMGP).

To enhance the level of safety of operation of sites with mass gathering of people, with the use of the project-oriented approach, it is recommended to pay special attention to the simulation modeling of mass service systems. This approach creates a unique design environment that requires description, studying and prediction of its state and behavior [1]. The application of this approach will be examined with the example of using schemes of mass service in projects of functioning of shopping and entertainment centers (SEC).

A site of mass gathering of people may be examined through the prism of many features of a complex system. In particular, these are macro-systems, the description of organization of which is not narrowed down to considering a single-type element (specifying the total number of single-type elements), openness of the system and capacity of self-organization [2, 3].

The uttermost methodological challenge of this research is to expand the tool set of knowledge. This tool set is used in planning, implementation and development of the institutions of safety provision of sites of this type.

The issue of safety provision for the sites at their operation stage is a time consuming task. The optimum option is to consider safety at the planning stage of a project. It is possible to implement through developing simulation the models of life cycles of sites with mass gathering of people. Implementation of such models enables us to identify all possible safety threats at the planning stage of a project. That is why development of simulation models of safety management in projects of creating sites of mass gathering of people is a relevant scientific task.

2. Literature review and problem statement

Study [4] considers scientific approaches to using cognitive modeling in projects of safe operation of nuclear power plants (NPP). A simulation model, presented in [4], allows us to assess the impact of new projects, programs and portfolios of projects in the field of protection of population from emergencies, in particular in projects of safe and reliable NNP operation.

Article [5] examined the mechanism of creating models of innovative projects, aimed at provision of power security on sites with mass gathering of people. This model forms the foundation for further research, aimed at its elaboration and expansion.

Paper [6] gives the analysis of methods and models of assessing the risk of emergencies. The authors proposed the model of assessment of emergencies occurrence on cites with mass gathering of people.

In [7], methodological grounds of risk-oriented approach were analyzed. These methods and models allow us to solve complex management tasks when implementing projects in the field of civil defense.

In study [8], peculiarities of risk management in the SMGP were considered, an approach to designing anti-risk measures, based on analysis of the project's life cycle by modeling the project indicators, was formulated.

In article [9], attention is paid to fundamental principles of risk management in the field of technological safety. The authors proposed the concept of anthropogenic risk management as the process approach in models of complex systems management. This research is the basis for further study, as it does not take into account other components of security: fire, social, environmental, anti-terrorism components, etc.

In paper [10], a system of indicators for the evaluation of safety levels of vital activity of the regions of Ukraine was proposed. Using the methods, presented in the paper, you can make the choice of projects for improvement of civil defense of those regions of the country that most need it. This system of indicators with certain modification and optimization may be applied for safety management projects on macro-systems of the SMGP type. Classes (fire and technological safety, social security, environmental safety), formed by the authors, may be more fully explored, optimized and applied with additions to complex systems.

When managing projects, programs and portfolios of projects in the field of life safety, it is necessary to take into account dynamic changes that occur in technical and scientific environment. New methods of information processing for providing operation safety are highly coveted in the information space of the SMGP system [11]. With the help of electronic implementation, in [12], authors experimentally demonstrate through mathematical modeling the increased productivity as a guide for recognition of successful information management in projects at the initial stage of their implementation. The outcomes of the work prove that delays in the information space of the elements of a complex system, even in its simplest manifestation, may perform efficient information processing. However, the authors do not pay attention to the problem of risk managing in projects of the SMGP informatization, which without a detailed analysis may augment research results in an unknown direction.

After characterizing scientific achievements of scientists, we can generalize that major shortcomings of implementation of projects and programs of creating complex systems are of similar character. It is worth noting that the most common is underestimation of the project budget and deviations from the project plan.

3. The aim and tasks of research

The aim of present study is to create a model of safety management in the projects of creating sites with mass gathering of people using the method of simulation modeling.

To achieve the set goal, the following scientific tasks were to be solved:

– to determine the need for using the method of simulation modeling to improve the level of operation reliability of safety-oriented management in projects of creating sites of mass gathering of people;

– to check reliability of using the method of simulation modeling with the example of safe vital functioning of a shopping and entertainment center.

4. Materials and methods for examining the intelligent methods of safety management

Construction of a simulation model of functioning of mass service systems at sites of mass gathering of people, using as an example of a trade and entertainment centre, is carried out by means of virtual libraries of software product AnyLogic (Russia).

The input data for calculation of the studied parameters included the square of horizontal projection of one person, motion speed of people of different age and sex (in emergency, comfortable and medium state), psychological state of customers, etc. To conduct the study, a simulation model was constructed.

4. 1. Description of the identification of threats of emergency at sites of mass gathering of people

Identification of security threats in the projects of creating SMGP is based on the hypothesis that risk includes randomness of unfavorable situation. It is not possible to predict accurately the probability of emergency, but predictability of adverse situations means existence of a mechanism of influence on a threat.

Complexity and a set of factors that affect management of these threats, in decision-making process requires processing a large number of different arrays of information, the amount of which increases each year. Therefore, to provide an in-depth analysis of rapid processes of emergencies and development of a short-term and long-term forecast of the possible course of events, happening during the situation of emergency localization or liquidation in projects of safe operation of the SMGP, the most effective is transition to the paradigm of safety-oriented management of projects and the programs of development of complex systems, which is advisable to consider using an event tree and a threat tree (Fig. 1).

A "threat tree" is a graphic orderly image of logical-probable connection of unpredictable emergency events (crises, disasters and accidents, emergencies, etc.) that lead to the final event, which is undesirable and dangerous for project safety. A "threat tree" is constructed by the principle from tops to roots (top down), establishing cause-effect relationships between hazardous unusual events and failures that cause them.

Implementation of safety-oriented management of projects of development of complex organizational and technical systems (creating sites of mass gathering of people) is possible with the use of informational-analytical system (Fig. 2). In the structure of the system, under conditions of an emergency, there is the module of addressing to databases of complex objects and organizational-technical systems (classification models of macro- and micro-level), as well as to the safety database (level of national, regional security, etc.).

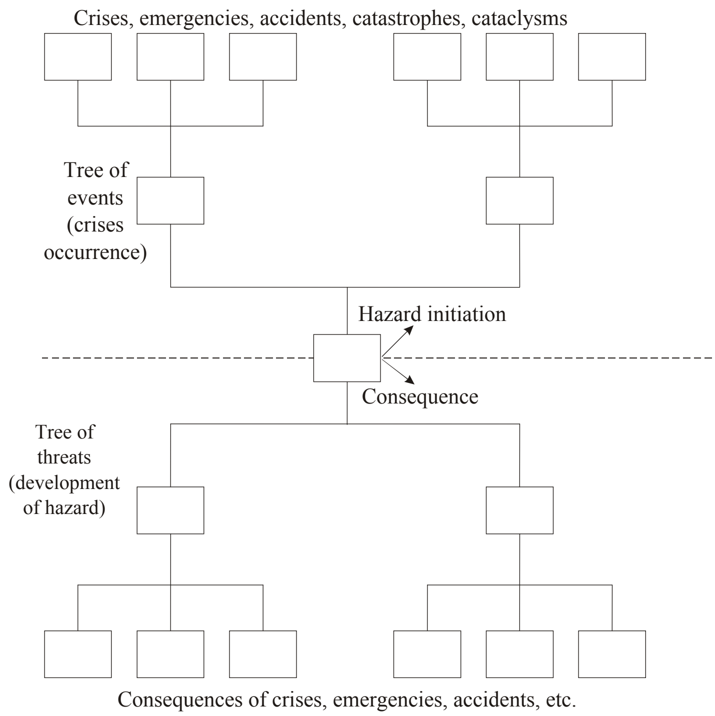

Fig. 1. Logical-probabilistic block diagram of emergency occurrence in the projects of creating sites of mass gathering of people

Fig. 3 shows a simulation model of the project of functioning of the site of mass gathering of people (shopping and entertainment center). The transformation of one state to another occurs with regard to the agents of the system (motion speed of customers, size of horizontal projection of a customer onto the plane, gathering of people, etc.). In the model, it is possible to change critical parameters of functioning of a shopping and entertainment center (SEC), and respectively simulate the main characteristics, such as pedestrian flow, throughput of a SEC, the most loaded points in the hall and critical time periods.

In Fig. 3, t_i is the time of client's staying in the shopping and entertainment center; Z_i is the input/output flow of clients; W_i is clients' waiting time in the service channel; K_i is the number of channel of service channels; n is the number of clients; P is the process.

Uncertainty in projects and programs of civil defense is divided into three types (depending on probability of occurrence of a particular event): complete uncertainty, partial uncertainty, complete certainty. Complete uncertainty is characterized by close to zero probability Pt of event occurrence (emergency occurrence). It is possible to express by ratio:

$$\lim_{t \to tk} Pt = 0, \tag{1}$$

where t is the time, tk is the final time of forecasting emergency.

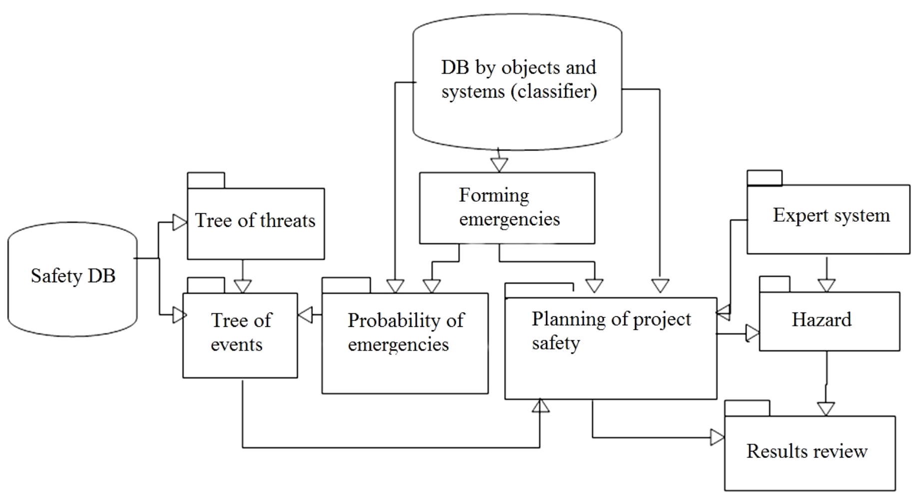

Fig. 2. Structure of system of planning safety of project of creating sites of mass gathering of people

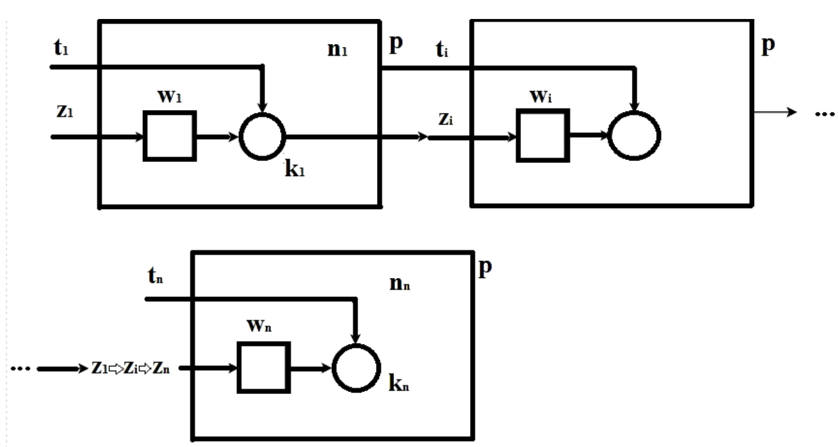

Fig. 3. Graphical representation of the simulation model

Partial uncertainty is characterized by events, the probability of which are defined within the area of 0...1, lies in the area of 0...1. It can be presented by inequality:

$$0 < \lim_{t-tk} Pt < 1. \quad (2)$$

Full certainty tends to the unit of event occurrence, mathematically it may be presented:

$$\lim_{t-tk} Pt = 1. \quad (3)$$

4. 2. Comparison of methods and algorithms of computer simulations of a life cycle of site with mass gathering of people

An analysis conducted revealed that the most effective for life cycle modeling in projects of creating sites with mass gathering of people is application of the method of simulation modeling. The use of computer technologies in simulation of the SMGP activity will makes it possible to verify visually the effectiveness of algorithm implementation even before the beginning of construction of the basic systems of structure functioning [13]. This will lead to savings of financial and time resources and will allow automation of the process and improvement of the final level of data accuracy. Formation of a model takes place due to the combination of parameters of speed of visitors' motion on a horizontal plane, data on the standard size of evacuation routes (staircases, door width, etc.), specifying the people flow intensity and other components.

The list of recommended algorithms that may be applied in simulation modeling of the project is presented in comparative Table 1. Categorization of methods for the sake of convenience of comparison was carried out with the help of anonymous survey of experts in the safety field, based on the Internet platform for LimeSurvey (USA).

Universality of a method implies adjustability of a method to the objectives of a project; the complexity of method reprogramming in case of its specificity. *Non-optimal* solutions are probability of occurrence of a non-optimal final solution, which has a negative impact on the set problem of safe functioning of the SMGP, compared with other methods and algorithms. The number of *input* simulation *parameters* contains all possible data that need to be included for running a process of imitation modeling. In general, the more input parameters, the more accurate the result of the outcome project product, however, we will take into account the effectiveness of the method operation at fewer inputs. *Duration of compilation* is an important component in time management of the project. In this case, we seek for the most accurate simulation level within limited time resources, so the optimal outcome of the given item is regarded as extremely important. *Substantiality* parameter allows us to determine the capability of the method to display real (as close to real as possible) properties of the processes in the project. *Deductivity* implies possibility of constructive use of a method or an algorithm to obtain the desired result. The final parameter of *effectiveness* is a set of all previous components, summed up at the point equivalent (green color is 3 points, yellow color is 1 point, red color is 0 points). In the final version, three most effective methods (the method of ant colonies [14], the Monte Carlo method [15] and the method of multi-agent optimization [16]) were obtained. This enables us to carry out simulation modeling of safety processes in projects of creating the SMGP at their planning stages. For further research and scientific-practical calculations in this problem range, we will use the method of ant colonies that best meets the needs of the project (Table 1).

5. Results of research into intelligent methods of safety management in projects

The threats of emergency occurrence when creating the SMGP at the planning stages are presented in the form of classification in Fig. 4, based on risk factors in construction projects and programs [17]. Mixed-type threats are universal, so they can be referred to both external type and internal type risks.

For convenience and visualization of all types of risk in projects of creating the SMGP, these threats were unified in the form of Table 2. Grouping threats by the type of impact on the project environment will allow the improvement of the state of security of a site at all stages of its life cycle [18, 19]. Universal threats (mixed type threats) include the risks that may occur in the internal as well as external project environment.

Table 1

Comparative table of recommended methods and algorithms

Requirements for method	Method of ant colonies	Monte Carlo method	Method of multi-agent optimization	«Cuckoo» method	Method of simulated annealing	Method of closest neighbor	Kruskal's algorithm	Prim's algorithm	Elastic network method
Universality	**High**	**High**	**High**	**Medium**	**High**	**Medium**	**Medium**	**Medium**	**High**
Non-optimal decisions	**Sometimes**	**Seldom**	**Seldom**	**Sometimes**	**Sometimes**	**Sometimes**	**Often**	**Often**	**Sometimes**
Input parameters	**High**	**Medium**	**High**	**Medium**	**Medium**	**Medium**	**Medium**	**Medium**	**High**
Duration of compilation	**Fast**	**Slow**	**Medium**	**Fast**	**Medium**	**Fast**	**Fast**	**Fast**	**Medium**
Substantiality	**High**	**High**	**High**	**Medium**	**Medium**	**Medium**	**Medium**	**Medium**	**Medium**
Deductivity	**High**	**High**	**Medium**	**High**	**High**	**Medium**	**Medium**	**Low**	**Medium**
Effectiveness	16	13	14	10	10	8	7	6	10

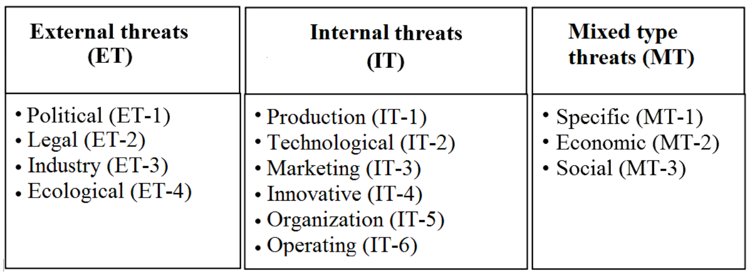

Fig. 4. Visualization of threats when managing projects of creating sites with mass gathering of people

Table 2

Description of threats in projects of creating sites of mass gathering of people

External threats (ET)	
ET-1	Unstable political situation at the state level; political confrontations between the city authorities and administration; threat of strikes
ET-2	Imperfection of legal base, level of liability for breaching contractual obligations when implementing the projects of construction of sites of mass gathering of people at all stages of the life cycle
ET-3	Communication management related to management in adjacent indusn trial areas; an alternative to switching to alternative economics
ET-4	Possibility of emergency of natural (storms, slippery roads, heavy rains) or technogenic character (increase in radiation level in a region, accidents in transport, etc.)
Internal threats (IT)	
IT-1	Production risks in projects of safe operation of the SMGP include transfer of systems of water and energy supply to non-operational state; poor quality of parts and materials of structures, faulty work of units and machines
IT-2	Emergence of works that were not foreseen at the stage of the project initiation; outdated technology of mounting and construction works on a site of mass gathering of people; reconstruction of badly executed works; etc.
IT-3	Fluctuations in pricing policy after the contract conclusion; price-cute ting by competitors; insolvency of a buyer
IT-4	Difficulty in implementing new computer programs in the SMGP; difficulty in usage of innovative materials; etc.
IT-5	Imperfection of project management in the field of managing organizat tional issues (supply of materials and equipment, problems with project documentation, etc.)
IT-6	Internal threats will also include the risks of operational nature: increase of authorities' demands for security of the SMGP, repairs and modernization of equipment, etc.
Mixed type threats (MT)	
MT-1	Anti-crisis management: urgent actions aimed at enhancing the level of project management
MT-2	Material and technical supplying of construction of a site with mass gathering of people: conditions of financial resources flow between all stakeholders of a project; unstable economic situation in the country; growth of prices for materials and work
MT-3	Moral and psychological state of all project participants; level of communication between all stakeholders of the project; the quality of working conditions

According to statistical data [20], a graphical web-model was constructed to display the level of threats at the planning stages (Fig. 2). Visual representation of this type of chart will make it possible to enhance safety-oriented management in projects of safe functioning of the SMGP.

External threats at sites of mass gathering of people at the planning stage (in percentage indication) are graphically represented in Fig. 5.

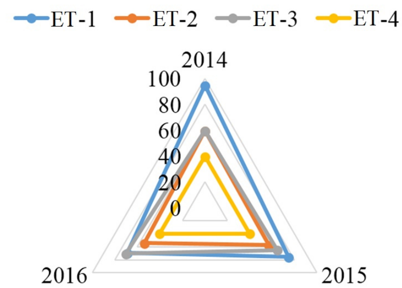

Fig. 5. Threat of external type at sites of mass gathering of people (at the planning stage)

The worst indicators according to [20] were obtained in 2014. This is due to the unstable economic and political situation, military actions on the territory of Ukraine and complicated social state of the population.

Risk factors of the internal type according to the classification (Table 1) consist of six points and are graphically represented in Fig. 6.

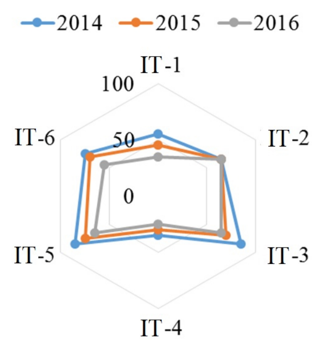

Fig. 6. Threat of internal type at sites of mass gathering of people (at the stage of planning)

Risks of internal environment are better subjected to management correction and preliminary actions, however the threats in the mass ratio are lower than the threats of external type. The tendency of critical 2014 and improvement of the situation are traced in the third quarter of 2015. However, the threat level remains at a high enough level (Fig. 7).

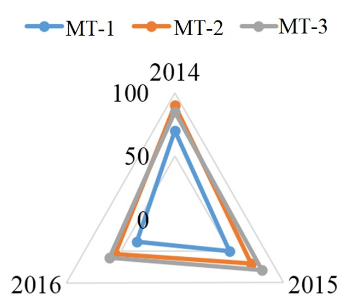

Fig. 7. Threats of mixed type at sites of mass gathering of people (at the stage of planning)

Construction of separated diagrams and collection of statistical data [20] allowed us to build (Fig. 8) a summary chart of threats at sites of mass gathering of people at the stage of planning.

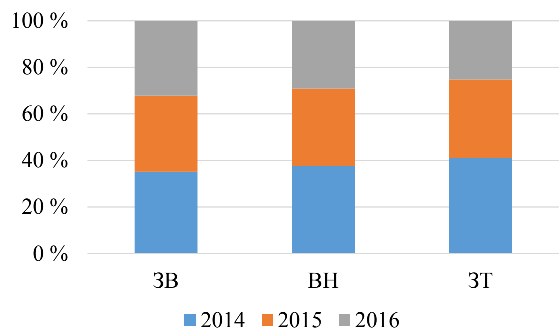

Fig. 8. Threats to the sites of mass gathering of people (in the form of statistical data)

Statistical data processing proved that the main feature of safety-oriented approach in project management is the aim to receive benefits (financial, social, etc) [21]. When implementing the projects of creating the SMGP, at the planning stage of the projects of this type, the issue of operation safety may be omitted. Graphic combination in Fig. 8 shows that emergence of threats of external type is growing every year (gray color area) against the background of threats of internal and mixed types, which tend to decrease. A decrease in emergence of threats in projects of this type is present only in areas where there is management interference in safety sphere.

In today's industrialized world, accidents (emergencies) at sites with mass gathering of people (fire, collapse of a part of a building, terroristic attack, failure of information system, etc.) are not uncommon. In recent years in Ukraine and in the world, there has been was a significant number of negative situations of this type. Among the most known:

– on January 24, 2011, a series of terroristic attacks took place at the airport "Domodedovo" (Russia). 36 people died, about 170 were injured;

– collapse of the roof of the shopping and entertainment center (SEC) Sky Mall, on February, 18, 2011 in Kiev, Ukraine. The collapse area was 500 m^2;

– emergency, caused by a fire at the shopping center "Admiral" (Kazan, Russia), happened on March 11, 2015 and took lives of 17 people;

– emergency was caused by a fire in the entertainment center Colectiv (Bucharest, Romania) an October 30, 2015. As a result of the fire, 58 people died and more than 160 were injured;

– a fire at the nightclub "Mi100" (Lviv, Ukraine). It happened on November 27, 2016 and was accompanied by collapse of a part of the building. The result of panic during emergency was a "crush jam", which led to casualties;

– as a result of a large-scale fire at a shopping center on January 19, 2017 in Tehran (Iran), more than 30 people died;

– the fall of a plane on the building of a shopping and entertainment center in Melbourne, Australia on February 21, 2017. The accident caused collapse of the building, and was accompanied by a heavy fire.

The probability of occurrence of these events could be mitigated by applying safety-oriented management to projects of creating sites with mass gathering of people [22, 23]. The selection of a particular security field at the planning stage will allow increasing the level of buildings and structures protection, which in turn will save health and lives of citizens.

For the identification of risks in projects of creating sites with mass gathering of people, a classification of safety threats for projects of this type, which is presented in Table 3, was developed.

Table 3

Identification of safety threats in SMGP at the planning stage

Classification features	Kinds of safety threats
Relation to the SMGP	– external; – internal; – mixed-type
Sources of occurrence	– threats from economic entities; – natural person; – authorities; – non-state structures
Object of influence	– threat to infrastructure; – threat to financial resources; – threat to the project team; – threat to terms; – threat to intellectual property; – threat to stakeholders
Duration of expression	– short-term; – medium-term; – long-term
Level of threat	– of crucial character; – very dangerous; – dangerous; – moderately dangerous
Duration of action	– constant; – temporary
Character of expression	– hidden threats; – clearly pronounced threats
Probability of occurrence	– probable; – hardly probable
Degree of uncertainly	– complete uncertainty; – partial uncertainty; – complete certainty
Sphere of occurrence	– social; – financial; – economic; – infrastructural; – political; – criminogenic; – technical; – scientific and technical

Projects of creating SMGP according to existing characteristics are related to complex projects, using the classifications of leading methodologies in the field of project management. A side result of a complex project is an increased level of costs of risk (provided in Table 3).

For convenience of working with complex systems in projects of safe operation of sites with a mass gathering of people, it is recommended to create a classification of complex systems in projects of civil defense (Table 4). This classification will make it possible to build up an idea of complex systems, which in future will optimize the implementation of projects and programs of a similar kind.

Using the classification, shown in Table 3, we have an opportunity to represent decomposition of a life cycle of functioning of a project (Fig. 5) of creating a site with mass gathering of people (which falls under classification of complex system).

The structure of the WBS construction in the sphere of life safety, namely in the projects of creating sites of mass gathering of people includes the functional elements of the given activity. In particular, construction of information-analytical data of security nature and their spread between stakeholders in projects of creating the SMGP, conducting expert studies, analytical and information activities, etc.

Table 4

Classification of complex systems in the projects of civil defense

<table>
<tr><td colspan="4">Interdependence of a system on the environment</td></tr>
<tr><td colspan="2">Open (there is exchange of resources and knowledge with the environment)</td><td colspan="2">Closed (there is no exchange of resources and knowledge with the environment)</td></tr>
<tr><td colspan="4">Origin of complex system in safety projects</td></tr>
<tr><td>Artificial</td><td>Natural</td><td>Virtual</td><td>Mixed</td></tr>
<tr><td colspan="4">Description of variables of complex system</td></tr>
<tr><td>With qualitative variables (there is only content description)</td><td colspan="2">With qualitative variables (variables exist discretely or continuously or are described by quantitative method)</td><td>Mixed description</td></tr>
<tr><td colspan="4">By type of description of the law of complex system functioning</td></tr>
<tr><td>Type “Black box” (law of functioning of a complex system is not completely known)</td><td>Non-parameterized (the law is not described, only some properties of the system are known)</td><td>Parameterized (the law is described, parameters are known)</td><td>Type “White box” (law of functioning of a complex system is completely known)</td></tr>
<tr><td colspan="4">By method of macro-system (complex system) management</td></tr>
<tr><td colspan="2">Systems, managed from outside</td><td>Systems, managed inside</td><td>With combined management</td></tr>
</table>

The abridged version of the WBS structure of the project of creating a site of mass gathering of people includes elements of project management according to ‘PMBoK’ methodology [24]. The initiation phase includes works that provide an idea of implementation of a project of this type. The planning phase includes a group of processes that are performed for generalization of the content list, goal and tasks setting and refinement. The longest (according to the international experience in realization of projects and programs) is the phase of the project, which includes a group of processes specified in the plan of implementation of the project. The longest (according to international experience in realization of projects and programs) is the phase of a project, which includes a group of processes, specified in the plan of a project implementation. This phase consists of processes of resource coordination (including human), managing expectations of stakeholders, etc. This phase includes sub-phases of project monitoring and control to provide implementation of changes and check if they comply with the project documentation. Completion phase consists of the processes, oriented to completion of all operations within the framework of project management. The phase of completion in projects (including creating SMPG) may begin ahead of time (for example, cancelled projects; projects that are in critical situation, etc) [24].

A simulation model of the studied structure and its behavior under conditions of normal operation and in case of emergencies is a formal description of its logical structure. Every single element of the system is subject to a simulation description [25] and provides indicators of certain value, in particular throughput of a building, number of people per certain plane, possibility of panic among visitors to the building, etc. Modeling of pedestrian flows, together with research into business processes of the SMGP, means of response to emergencies, information environment [25] transport flows of an adjacent territory of the SMGP, form a system of safety management in projects of this type.

Fig. 9 shows the model of simulation modeling of the life cycle of a project of creating a shopping and entertainment center (according to classification features, component of SMGP). The building is represented with consideration of the shopping sector, security sector and recreation sector. For calculation of throughput capacity, the sector of grocery stores was not considered.

In the model, besi’des parameters of the building, static data were assigned: number of employees, security, supporting staff, visitors, working vehicles, which are correlated within insignificant statistical limits.

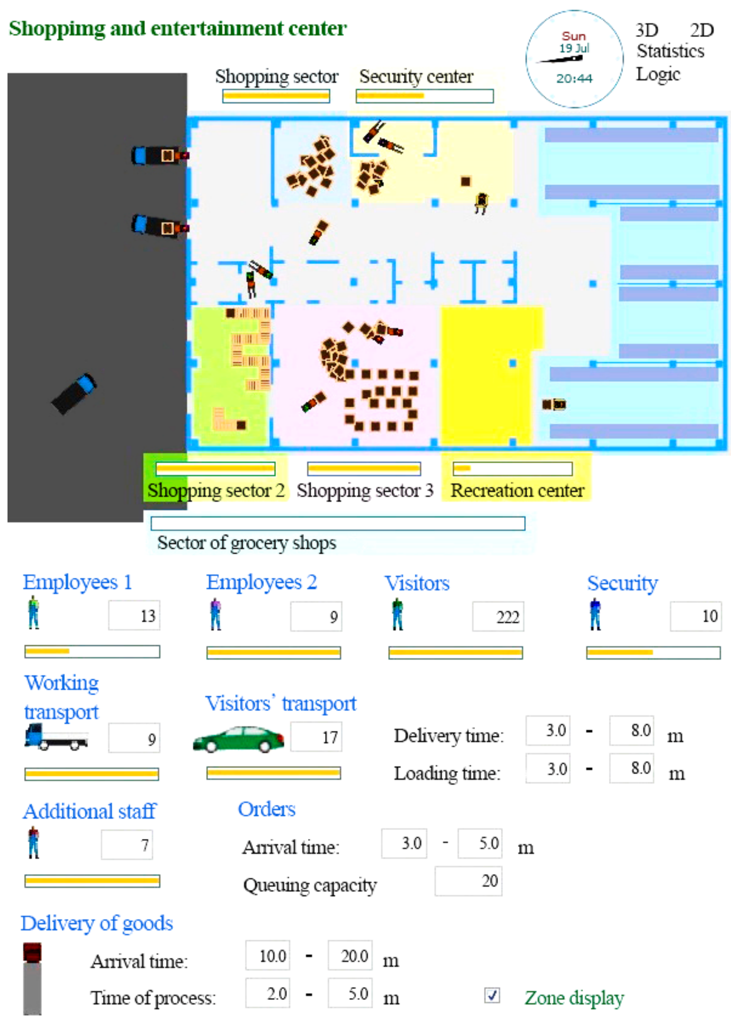

Fig. 9. Simulation model of life cycle of project of creating a site with mass gathering of people

A simulation model considers parameters which are given to the system input:

– geometric and architectural parameters of the project product;

– forecasted pedestrian flows, which are set as input parameters of the simulation model;

– number of visitors;

– arrival points;

– opening time of separate outlets (for example, opening time of shops in trade and entertainment centers);

– standard value of motion of human flows, conditions of their changing (movement up and down the stairs, overcrowding, etc.).

The received parameters allow us to make an idea of safe functioning of SMGP:

– arrival time for visitors;

– time of goods delivery;

– time of taking orders;

– existence of "bottleneck" zones;

– etc.

Identifier of sectors filling allows reacting timely to possible overcrowding with visitors to certain zones and introducing adjustments at the planning stage of the project.

Fig. 10 shows the dynamic model of simulation environment of the SMGP lifecycle, which includes: the process of visitor' arrival at the SMGP territory, his chaotic stay in areas of the building (shops, kiosks, shopping halls, entertainment places, etc.), and departure from the area, surrounding the SMGP (problem of occupation of parking areas and their simulation in case of emergencies are not considered).

6. Discussion of results of simulating safety parameters of a lifecycle of a site with mass gathering of people

Obtained as a result of computer experiment, the outcomes of simulation modeling enable us to estimate basic parameters of safety operation of a site with the mass gathering of people: throughput of a site, peak hours of critically permissible loading, maximum number of visitors, etc. By means of simulation models, it is possible to simulate basic operating processes of functioning of a site with mass gathering of people.

To evaluate the safety parameters of the site by means of a computer simulation model, we conducted the experiment of the process of evacuation from the building because of the conditional emergency of "putting a mine in the institution". Simulation results proved admissibility of geometric parameters of a building and architectural solutions to provide the standards of evacuation. In the future, it is possible to extend probable scenarios of threats and emergencies in a shopping and entertainment center by means of a specialized system that contains the tree of events and threats. A simulation model makes it possible to explore visually the parameters, set for the calculation of safe operation of the building and include their editing and correction. The working screen of the model consists of the following components: project resources, storages and related elements, parameters of the models, loading of the system elements, block-scheme of premises of the SEC, schedule of the outflow and flow of the SEC processes.

Development of the simulation and dynamic models of projects of creating the SMGP will make it possible to save financial resources and, what is the most important, the life and health of citizens while designing the building and its safety characteristics.

To provide a reliable state of operation of sites with mass gathering of people at the initial stage of operation, many methods have been used recently to enhance safety characteristics and reliability of buildings of increased danger. However, as statistical data indicate (Fig. 8), the number of external threats is growing every year. In this paper, we used the method of simulation modeling of the project of creating a site with mass gathering of people to determine the "narrow" places, which need special attention in order to minimize the negative consequences in case of emergency. Usage of this method allows us to draw conclusion about compliance of geometric parameters and architectural solutions of the project of a site with mass gathering of people at the stage of planning with the security requirements, set at this stage.

7. Conclusions

1. The model-scheme of threats during management of projects of creating sites with mass gathering of people was developed, which enabled us to formalise the process of safety-oriented project management.

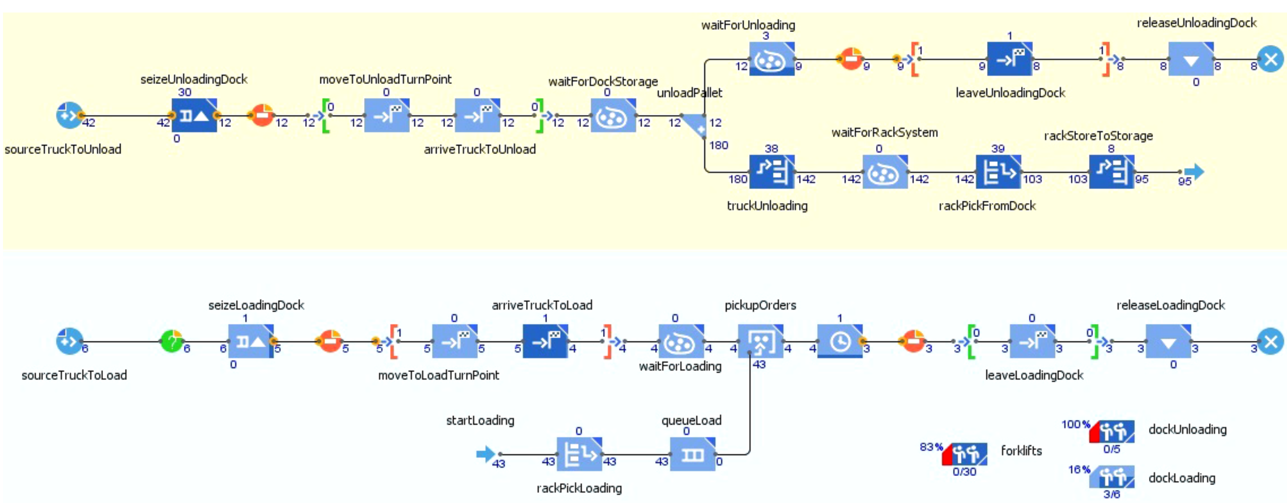

Fig. 10. Dynamic model of simulation environment of the life cycle of sites of mass gathering of people

2. Classification of complex systems for the management of projects and programs of the civil defense system was proposed. This provided the opportunity to unify the project of creating a site with mass gathering of people. The structural decomposition of a typical project was created.

3. We conducted a comparative analysis of the methods and algorithms through anonymous survey of experts in the field of security as for the use of simulation modeling in projects of this type. This made it possible to substantiate the necessity of using methods of simulation modeling with the help of the algorithms of ant colonies, using agent software models AnyLogic.

The employed method of simulation modeling with the help of software may provide an opportunity to improve the accuracy of simulation of the basic operating processes of functioning of a site with mass gathering of people at the stage of project planning.

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RESEARCH ON DRIVERS' REACTION TIME IN DIFFERENT CONDITIONS

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Проведені експериментальні дослідження дозволили визначити залежність між функціональним станом водіїв та часом їх реакції у лабораторних та реальних умовах. На основі цих досліджень можна визначити, наскільки формування часу реакції та його складових залежить від психофізіологічних особливостей водіїв та впливає на безпечні режими руху. Результати роботи необхідно враховувати для розробки автоматизованих систем управління дорожнім рухом

Ключові слова: функціональний стан, час реакції, швидкісний режим, автоматизована система дорожнього руху

Проведенные экспериментальные исследования позволили определить зависимость между функциональным состоянием водителей и временем их реакции в лабораторных и реальных условиях. На основе этих исследований можно определить, насколько формирование времени реакции и его составляющих зависит от психофизиологических особенностей водителей и влияет на безопасные режимы движения. Результаты работы необходимо учитывать для разработки автоматизированных систем управления дорожным движением

Ключевые слова: функциональное состояние, время реакции, скоростной режим, автоматизированная система дорожного движения

1. Introduction

Currently, the most unpredictable aspect of road safety is the driver's behavior. The information load and the road conditions have a significant effect on the driver, especially if the amount of information is scarce or excessive. The accuracy of accepting and producing actions, which is understood as the driver's reaction time, depends mainly on the psychophysiological state [1]. Among the main indicators that make it possible to analyze the functional state in detail, the important factors are the stress index (SI), the regulatory system activity index (RSAI), as well as the frequency and average amplitude of the rhythms of the electroencephalogram (EEG) [2–4].

The driver's reaction time is the manifestation of a complex mental process. Understanding, prediction, and management of this reaction are possible only after determining the psychophysiological mechanisms of the entire process of perception. In a study of the driver's response to stimuli, it is necessary to take into account the driver's functional state. Otherwise, it is impossible to explain the factors such as the ambiguity of the time of reacting to the same signal, a change in the response time, or a shorter duration of the reaction time [5].

The driver's reaction time largely depends on the speed and the accuracy of the appropriate actions to stimuli (pressing the brake pedal, turning the steering wheel, switching the gear, etc.), especially at a high speed [6–8]. The driver perceives increasing amounts of information about the road users, vehicles' regulation, the road condition and the environment, as well as about the work of the car's systems and parts. In addition, the driver needs to analyze continually any information input and to make decisions, often in shortage of time. Long and intensive work of a driver results in a hypertension in the driver's nervous system and requires constant discipline and attentiveness. This significantly affects the functional state. Often, it is just the latter circumstance that causes road accidents [4].

The reaction time of drivers in most cases determines the correct selection of the movement mode and affects road safety. Therefore, the results of the study of the psychomotor reaction with regard to the driver's functional state can help improve road safety. The findings of the