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Optimization of Parameters of Technological Processes Means of the FlexSim Simulation Simulation Program

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***Abstract*— the study of functional processes of mechanical multiparameter systems becomes an urgent task during the fourth industrial revolution, when data becomes the most important aspect in this field. Research of the input data influence, changes in the process of mechanical system modeling, analysis of the interplay of different parameters relationships is an important task to ensure the most efficient production operation. The article presents results of the analysis and practical application of the mechanical systems study results in the area of mechanical engineering, manufacturing of equipment for various functional purposes,as an example, electronics, processing and food industries, etc. The necessity of technological systems creation processes simulation and visualization of actual data for further analysis of their relations, the state of mechanical system operation for the mechanical equipment manufacture, as well as the analysis of production processes for the efficient use of resources and time component of processes are shown. Examples of constructing simulation models of production processes in the FlexSim environment are given to research the impact of data relations that describe the operation of each object in particular and certain affect the overall system process. Research methods of practical use of relations of many independent parameters models of the system are offered.**

Keywords— input, output, multi-parameter technical system, information graphic technology, mathematical modeling, FlexSim simulation system.

I. INTRODUCTION

Program **Industry 4.0 (Industry 4.0)** defines the rapid development of information technology, automation of manufacturing, robotics usage in enterprises in Europe. Management of production, packaging, sorting, etc. is done in real time, using data that updates every second. It is important to take into account influence of external factors on the technological process [1, 2, 3]. Creating virtual copies of mechanical engineering objects, modeling the interaction processes of different parameters of the system operation in general, the impact of data on each system object separately describes the general scheme of production. An important role is played by Internet technologies for the modern automated enterprise, since the **Internet of Things** has become an integral component for design optimization, assembly of a product, technological process adjustment of machine-
building industry. An important step in modern production is processing of large amounts of information, data (**BigData**) using cloud and artificial intelligence (**Artificial Intelligence**) technologies. An operator who controls engineering process at any stage must receive the processed data as quickly and conveniently as possible to analyze and decide on their further use in the technological process. Given the above stages of modern production, the urgent task is to use specialized IT platforms, business process management systems, modeling different stages of production, sorting, assembly, analysis of equipment, etc. (Fig. 1).

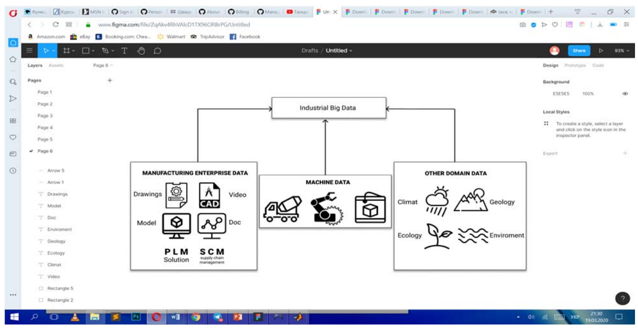

Fig. 1. Structural diagram of the factors that make up **Industrial Big Data**

Data that covers the parameters of the entire process, ie Industrial Big Data include the following components: data on the project **Manufacturing Enterprise data** (drawings of the production object): drawings of objects **Drawings**, 3D - model, video, documentation, etc.; **PLM** solutions (**Product Lifecycle Management**) [1], product lifecycle management. These are information management systems in which data, processes, business systems and employees

are combined into a single informational space. PLM systems allow you to manage important information throughout the product lifecycle – from idea, design and production stages to maintenance and disposal. Such systems mainly contain mechanical processes of the industry production cycle, managed through the implementation of **PLM** software. Therefore, being an expert in mechanical engineering, it's easy to understand and customize **PLM** software to meet industry needs;

SCM (supply chain management) [1, 2] is a management and organization strategy that approaches management of the entire data flow of raw material, materials, products, services that appear and change during the implementation of logistics, production processes. The purpose of this strategy is to obtain an economic effect (reducing delays, controlling demand for products, etc.).

The next component for **Industrial Big Data** is **Machine Data** [1, 2, 3], which we get directly from production, information about an object or process: time, pressure, speed, temperature, etc. It is **Machine Data** (**Time Series Data**) that is the most voluminous of all data and changes every hour, minute, second.

Other data that affects **Industrial Big Data** are environmental, ecological, climatic, terrain, and more. They determine the main characteristics of the equipment, adjusting the process of processing the object, its manufacturing, etc.

Well-known scientific studies that thoroughly investigate the processes of data collection and processing for industry, model the input and output parameters of technological enterprises. Thus, [1, 2] discusses some aspects and approaches for creating algorithms for complex hierarchical systems of industry, oriented on business analyst, the manager of enterprises, intended for individual choice of models for modeling of various practical problems, taking into account input parameters.

II. Problem statement

In the structure of industry the highest share is occupied by the branches of ferrous metallurgy, mechanical engineering, electric power, chemical and food industries. Gathering and analyzing data that affects the technological process of these industries is an important element in modeling the steps of creating, processing, sorting parts, or products. Mathematical process modeling allows you to analyze the structure of work and use data to analyze predicted results, change the number of data flows, and more. Geometric modeling provides visualization of the relations between different system parameters. It is effective for multi-parameter systems where the number of system parameters exceeds three. Simulation modeling allows you to combine the two steps and create a logical, mathematical description of the process that will visually present the design results, evaluate the operation of the process and provide a direct impact on the design result in real time. Visual representation using inputs that affect the operation of each object, allows you to better regulate the relations between the objects and to track emergency situations or changes at each stage, that lead to economic losses. Presentation of mechanical systems research results in the **FlexSim** software environment **makes** it possible to optimize the parameters of the system, taking into account its versatility for the study of technological systems at different stages of the product life cycle.

Therefore, the production engineer should have an overall outline of the production line and understand the impact of the data that changes over time for each step. In our opinion, this is effective when creating a simulation model of the process as a whole and separately for each stage of the technological process. The algorithm for constructing a map of processing data creation process can be :

- analysis of the input data taking into account the process features;
- creation of a mathematical model where the relations between different parameters and the interaction between the stages of the technological process are researched;
- creating a simulation model, researching possible contingencies by looking into possible combinations of data that create problem areas in the process;
- prediction of changing parameters, initial data, relations between objects, complication or simplification of technological process model of mechanical engineering to save resources, time;
- possibility to implement changes to model creation.

The development and study of the functionality of simulation models for the analysis of technological systems is an urgent task for modern production.

III. Stages of research of production problem and creation of its model

In order to study the technical system of production, it is first of all necessary to process the data related to the process. Consider a system structure denoted by its ***St .*** It is described by many elements of the system

$$Me = \{e1, e2, e3,\ldots\} \quad (1)$$

and the many relations between them

$$Z = \{z1, z2, z3\ldots\}. \quad (2)$$

Then

$$St = \{Me, Z\}. \quad (3)$$

The behavior of such system (3) is effectively investigated as a sequence in time of its states. Each state of the system is affected by certain external factors, which are also taken into account in the simulation. The use of a simulation model improves the search for rational solutions in the management of an industrial enterprise. We distinguish the main stages of research and analysis of the model:

1. Formulation of goals. Allocation of a goal (multiple goals) that must be reached during management.
2. Definition of the object of management (research). This stage involves a detailed analysis of the part of the process (or the whole process) that interests the engineer and is based on the goal. At this stage, a description of the factors influencing the technological process, the environment, select several variants of the object and choose the appropriate variant on one or more criteria.
3. Structural optimization of the model. This stage consists of the following steps: determination of input and output parameters of the object, selection of structural elements of the model, changes of parameters.
4. Correction of the whole control system, all stages of control: selection of system elements (trimming elements), changing the structure of the system (inputs / outputs of the model).

Analyzing the parameters that affect the model as a whole, we can draw up a model structure that describes the relations between different parameters that affect the flow of the industry process (Fig. 2).

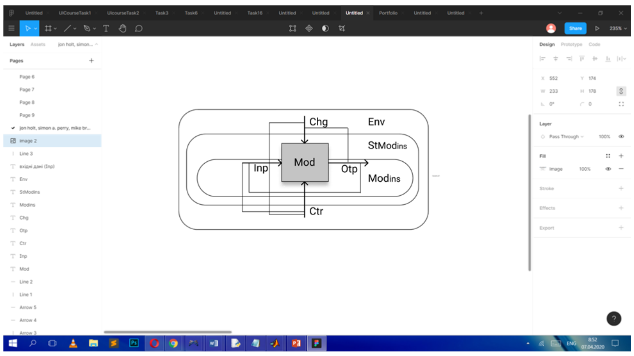

Fig. 2. Relationships between different parameters that affect the process

Consider the process modeling of industrial processes in accordance with Fig. 2.

The study of the **Mod (Model)** of the enterprise takes into account the influence of the following parameters:

Inp - (Input) input: This is information about objects managed by an industrial enterprise, an information stream that comes describing the process;

Chg - (Changes) changes made during the research process, (data entry, variables, relationships);

Ctr - (Control) control rules, their relations and the impact on the process as a whole and on the simulation results. **Chg and Ctr are** interrelated, since the quality control of the modeling processes can be done through changes in the input data that characterize the modeling objects. Output results in **Otp** (**Output**), which are related to the following variables:

Inp (input);

Chg - changes that are made during the study of the modeling process.

The set of data sets and relationships between parameters is investigated in the following spaces:

Mod ins are internal processes that take place within the model and describe the set of relationships between the various parameters that affect the **Mod** process**.**

Env - the influence of the environment on the process of changing external data and their impact on the processes **Mod in;**

StModins is a structure of a modeling process that incorporates **Modins** internal processes and the influence of external factors **Env.**

For the study of industrial lines, we have chosen the **FlexSim** environment, which is effective for simulation. Consider modeling on the example of the process of sorting products in a warehouse with the involvement of the operator [4, 5]. The model can be effective for detecting defects in batch production or checking for product quality (Fig. 3).

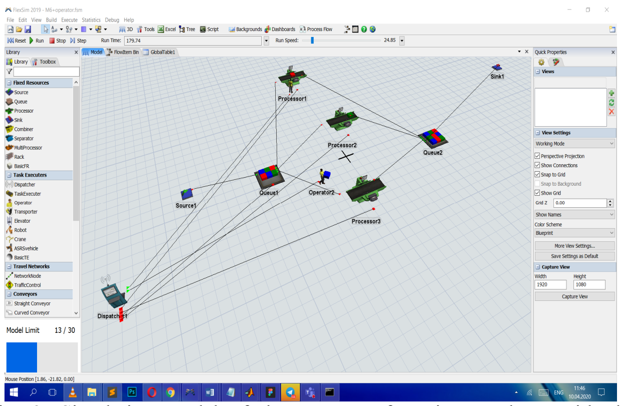

Fig. 3. Simulation model of the process of sorting products with the involvement of operators

The proposed scheme consists of the following objects:

Source1 - object creation,

Queue1, 2 - queue, assembly point,

Operator 1, 2 - operators,

Dispatcher - an object designed to control the operators.

Processor1, 2, 3 - processors,

Tote - sort object,

Slink1 - exit, process stop point.

In the properties of **Source1** (Fig. 4) we enter data on the type of products being investigated and the number of objects at the entrance. For this example, we obtain two types of output as follows:

Source - Triggers - On Creation - Set The Item Type and Color - Item Type - duniform (1, 2, getstream (current)).

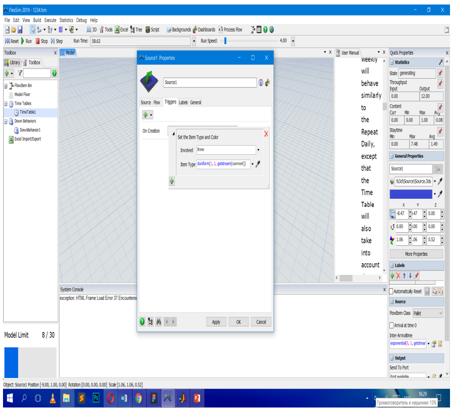

Fig. 4. Enter the initial data to work in the **FlexSim** environment

For each object in the **FlexSim** system, **it is** possible to choose the type of distribution (Fig. 5). The **Source** object specifies the data for the distribution of objects, information about the selected port for the movement of each object. The path to determine the port for object movement is as follows:

Source - Send To Port - First available.

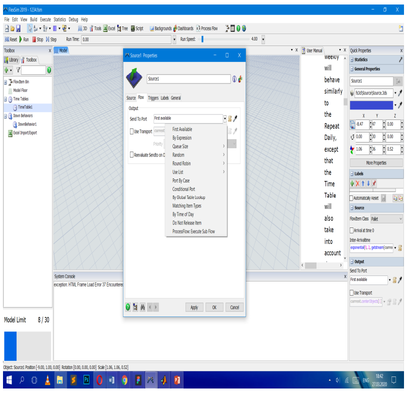

Fig. 5. Select the type of object distribution for **Source1**

During the development of a simulation model of products sorting process involving the operator, the impact of different data on each object in particular and on the system as a whole was analyzed. In Fig. 6 shows a diagram of the relation between model parameters and the display of data that affect each object in particular.

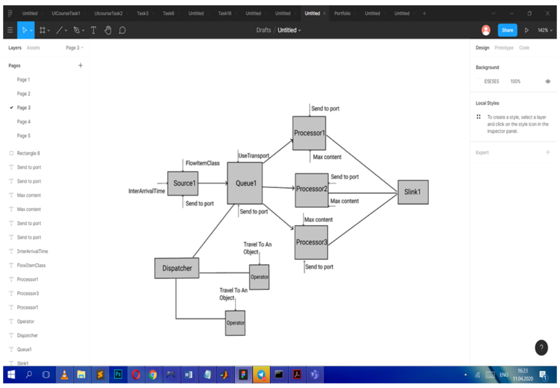

Fig. 6. Scheme of the relationship between the model parameters and the display of data that affect each object in particular

The first step is to set the input for the **Source1** object . Here are the main types:

Inter - ArrivalTime, FlowItemClass, SendToPort.

The **Inter - ArrivalTime option** determines the time of arrival and the type of data distribution, where we select the data to be distributed as follows:

exponential (0, 2, getstream (current)), where

num *exponential* (num *location*, num *scale* [, num stream]).

Value type **num** determine how often flows are created (in seconds) that returns a unique random data stream associated with the object.

The **FlowItemClass** option allows you to select the type of objects, for example, in this case **Pallet is** selected. Among the known options is the ability to select objects of different geometric shapes (**box, cylinder, sphere, circle, pallet, track,** etc.) to study the features of technological processes taking into account the structural shape of models, parts, products, etc. The program also allows you to create your own type of object, to give it the necessary characteristics:

Source1 - Source - FlowItemClass - Go To FlowItemBin.

The data to be entered in **SendToPort 'is** responsible for the number of ports and the principle of allocation of objects or parts, respectively, for each port. The way to specify this option is as follows:

Source1 - Flow - SendToPort –GoToFlowItemBin - FirstAvailable.

FirstAvailable is a type of object allocation that does not require a port number and number of objects, a feature distribution. This type of object distribution allows them to move in one direction only, since only one port and one direction are specified. Otherwise, you must specify a condition for the distribution of objects by the given characteristics, for example: **By Expression**, **Queue Size, Random, Port by Case, By Global Table, By Time of Day**.

Consider the **Queue1** object (Fig. 6) for which the following data is given: **Maximum Content**, for example, 5 units is the number of units of parts or products that will accumulate at a station before moving to the next station. There **are** two ports connected to **Queue1**, that is, two object directions. You must specify a destination for each product type by selecting **Port by Case** or setting an arbitrary direction of travel

Source1 - Flow - Send To Port –
Go To FlowItem Bin - Port by Case.

For **Processor1, Processor2, Processor3,** we enter data corresponding to the number of objects at the specified station and obtain the number of input and output ports corresponding to the number of connections (Fig. 7).

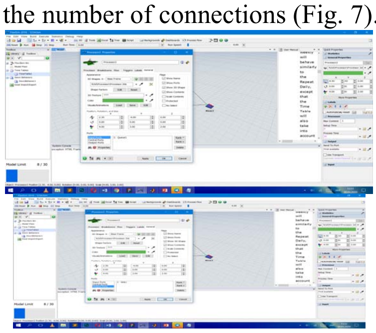

Fig. 7. Input and output ports for **Processor1, Processor 2, Processor3** objects

The **Slink1** object (Fig. 6) is a process stop, a simulation end, an exit.

In order to optimize the processes of the engineer, it is necessary to analyze how it is more efficient to move parts or objects to other stages of the technological process, whether to involve the operator, or to program the types of products sufficiently for further distribution. You need to calculate these questions, create a simulation model and compare the options. Therefore, modeling processes in the **FlexSim** environment is an effective way to explore and analyze different solutions to a single problem.

IV. SUBSTANTIATION OF BASIC STAGES OF RESEARCH, ANALYSIS OF STATISTICS AND VISUALIZATION OF SIMULATION DATA IN FLEXSIM ENVIRONMENT.

The analysis shows that in the study of processes using simulation of technological processes in the **FlexSim** system, there are five main stages of the study [8, 9] on (Fig. 8).

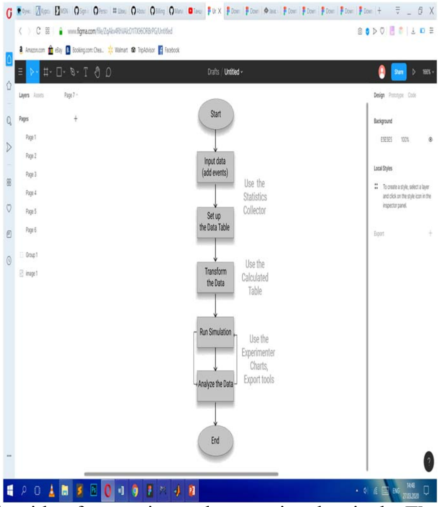

Fig. 8. An algorithm for entering and processing data in the **FlexSim** system

The first step is to set objects, enter data, create events, and build relations between objects. We use **Statistic Collector** to view standard statistics for each object**.** The standard statistics overview for a 3D object in real time is as follows:

3D model - 3D object - Quick Properties - Expand button.

In particular, we use the processing of these types of data using the **Statistic Collector** option. These options are contained in the Statistic group tab, which automatically expands when the simulation process starts. In Fig. Fig. 9 presents statistics of the **Queue1** object of the simulation model of the process of sorting products with the involvement of operators, which is shown in Fig.8.

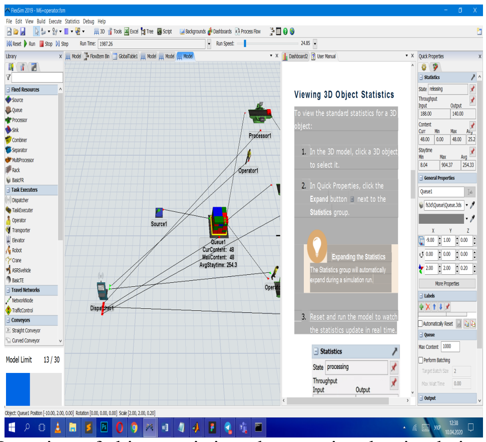

Fig. 9. Overview of object statistics when starting the simulation process

The next step in the **FlexSim** data processing algorithm is **Transform the Data**. We use **Calculated Table** to work with the data**. Calculated Table** can transform data obtained from **Statistics collector in** many ways: filtering, comparing, using advanced calculations, and more.

Once the simulation process is started, it is possible to analyze the data using **Dashboard** and **Use the Experimenter Charts.** For example, we analyze the dependence of the content of objects at a given station on time by creating a **Dashboard (Statistic - Content - Pin to Dashboard - Content vs Time)** (Fig. 10).

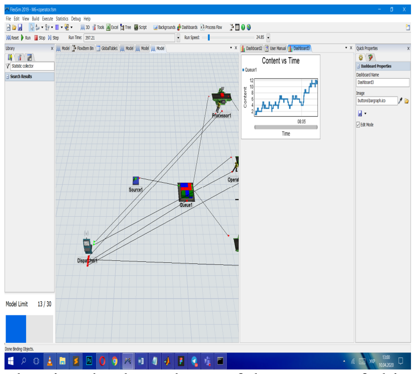

Fig. 10.Graph showing the dependence of the content of objects in a certain time interval

We see that in a certain interval of time (8 seconds) the number of units (4 pieces) that passed through this station was obtained.

V. SUBSTANTIATION OF TECHNOLOGICAL PROCESS FOR THE FOOD INDUSTRY (FOOD INDUSTRY) ON THE EXAMPLE OF THE JUICE BOTTLING PROBLEM. CREATION OF A SIMULATION MODEL OF THE PROBLEM BY MEANS OF FLEXSIM.

Consider the technological stage of production and bottling of juice (Fig. 11). The main production sites for the production of juice are the preparation of raw materials, dosage - mixed section, bottling and finished goods accounting. An important stage is water treatment. The water is purified and softened. The recovery of concentrated juices is that, with the help of special equipment, the moisture is recovered, that is, the prepared water is added. The next stage is the preparation of the container: the receipt of the container on the bottle washer, then on the labeling machine, dosing and filling machine, a special sealing machine. A visual inspection machine is also required in order to notice a defective product [4].

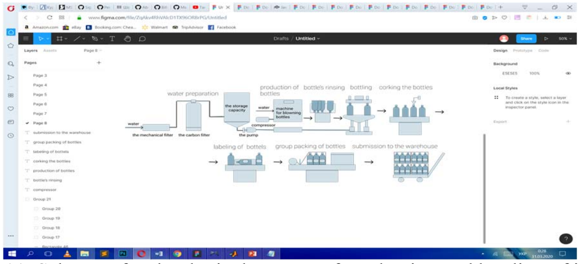

Fig. 11. Scheme of technological process of production and bottling of juice

The process of packing juices is to optimize the entire supply route, taking into account the interests of the manufacturer and the end consumer. Therefore, it is important to calculate the main steps and analyze them. For analysis, we considered the problem of constructing a simulation model of the operation of the juice bottling line. An empty bottle is sent to the line every second, sent to one of three sinks, each of which processes it in 3 ... 5 seconds. The bottles are then fed to a dispensing machine that spends 2 seconds filling each bottle. After that, two packing machines seal the bottles and stick labels. In this case, 10% of bottles are discarded. and optimize the simulation model of the shop [6, 7, 9].

FlexSim environment was used to create a simulation model of this technological process (Fig. 12).

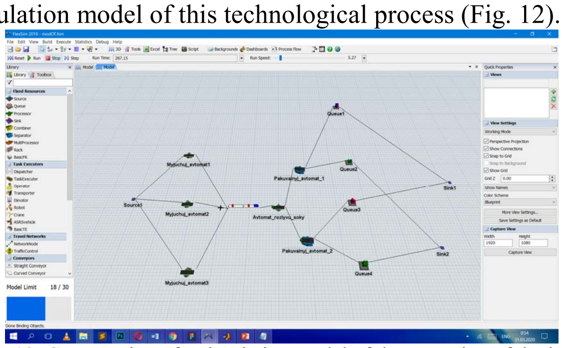

Fig. 12. Construction of a simulation model of the operation of the juice bottling line

From the **Source1** source, imitation models of bottles for three **Myjuchuj_avtomat1, Myjuchuj_avtomat2, Myjuchuj_avtomat3** washing machines are **included every second**, among which there are defective ones (Fig. 13).

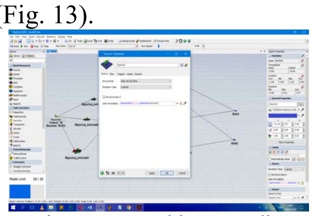

Fig. 13. **Source1** properties to output objects to a line

Assigning three objects to the simulation model of the problem is as follows:

Source1 - Triggers - OnCreation - SetItemType and Color - ItemType - duniform (1,3, getstream (current)) in Fig. 14.

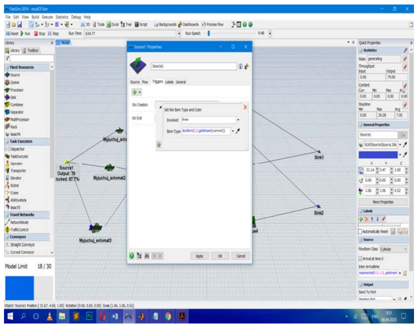

Fig. 14. The way to specify three types of objects

For the demonstration of defective objects is indicated in green in Fig. 12.

By the condition of defective bottles of 10%, so we denote this number of objects at the input, and set the other two types 45% and 45% equally to fulfill the initial condition (Fig. 15): **Source1 - Triggers - OnCreation - SetItemType and Color - Data - Set ItemType by Percentage.**

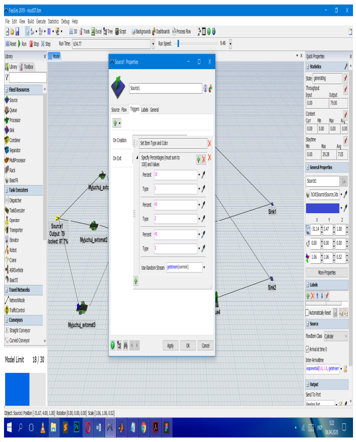

Fig. 15. Specifying object types

From the three washers, the bottles are fed to the conveyor, from where they move to the dispenser (**Processor** 1). After that, they arrive at two **Pakuvalnyj_avtomat_1** packing machines**, Pakuvalnyjavtomat_2**, which seal the bottles and fit the labels. At this stage, the bottles are discarded. To model this stage, we selected a **Separator** object from the **FlexSim 2019** library, named **Pakuvalnyj_avtomat_1** and **Pakuvalnyj_avtomat_2** for both stations, and added the following properties for the sort operation (Fig. 16):

Packing_Automat_1 (Packing_Automat_2) - Separator - Split - Split / Unpack Quantity - By Percentage;
Use Random Stream - getstream (current).

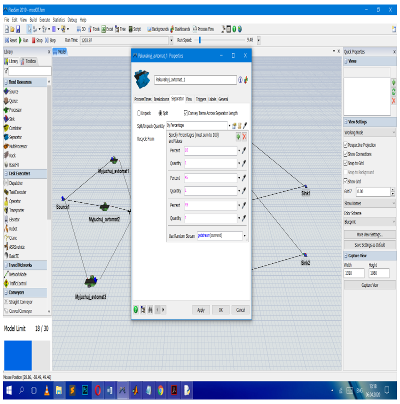

Fig. 16. Bottle rejection data entry

Queue 2 and **Queue 4** queues select discarded products that go to **Slink2** (recycle). **Queue1** and **Queue 3** turn into warehouse products (**Slink1**).

Using statistical analysis, it is possible to observe the frequency of receipt of defective bottles at the **Queue2** and **Queue4 station** for a given period of time in seconds (Fig. 17).

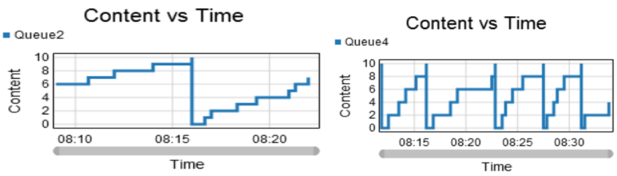

Fig. 17. Graphs showing the number of defective bottles (units) arriving at the station in the allotted time

VI. Conclusions

The result of the development of a structural model of the study of relations between different parameters of technological processes of industry is presented. The steps of data study necessary for simulation in **FlexSim 2019.** The following advantages of using this environment for specific tasks, such as the food industry, are demonstrated:

1) a simulation model of the juice bottling process allows to obtain information on various aspects of the technological process depending on the input factors;

2) the simulation model allows to investigate and analyze the process in cases where analytical calculations and mathematical programming fail;

3) it is much easier to develop an imitation model than an analytical one, since the process of creating an imitation model is step-by-step and modular;

4) the sructure of the simulation model naturally reproduces the structure of the process for which the model is built;

5) a significant advantage of simulation modeling in the process of solving the proposed type of problems is the ability to explore the model in time and create an animation of its behavior, which allows you to quickly find errors.

FlexSim simulation simulation also allows you to meet the challenges of other types of industry: mechanical engineering, electricity, chemical, transportation and transportation logistics etc.

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Informational Graphic Technologies for Fire Safety Level Determination in Special Purpose Buildings

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***Abstract* — The article deals with the problem of public awareness about existing special purpose buildings such as protective buildings and shelters that can be used to protect against emergencies. The status update on the problem is considered. During research were analyzed recent scientific papers in the field of modern information technologies integration into civil protection system. The necessity of using modern informational graphic technologies for fire safety level determination in such type of shelters was substantiated. The features of actual data visualization with the involvement of mathematical transformations and methods of visual information graphing are investigated. Based on the offered methods of visualization graphics information has been developed software emulator "Fireware Emulator". It can be used for fire safety level determination in buildings of such type.**

Keywords— informational graphic technologies, software emulator, shelter, civil protection, room plan.

I. Introduction

The current integration state of modern information technologies to human life environment initiate appearance of new natural threats which can be serious risks to its normal and safety life. Military conflicts and the risks to use mass destruction weapon forced us to make protective purpose buildings - safety places such as housing units and shelters where peoples could stay and live during emergency situation.

Based on the daily facts of human life process both society and its individual members, we observe a progressive tendency towards increasing potential threats to humanity. The amount of the increasing anthropogenic and natural character risks is proportional to the number of tasks to be undertaken to ensure the safety of human life. Among these problems we could highlight the problems of peoples safe staying in protective purpose buildings: housing units and shelters.

The process of necessary building choosing is based on own human's preferences, its geographic location, type of emergency situation and other additional factors. But the most important among them is security (Fig.1). First, in such protective building, user should to determine the state of fire safety, the possibility of safe evacuation from the rooms and the comfortableness level of staying. After it, on the basis of visualized data about protective building, human should to analyze the possible deterioration causes of the situation in the shelter and to identify ways to better its planning. All upgrades must be produced by taking into account the position of ensuring proper level of fire safety.

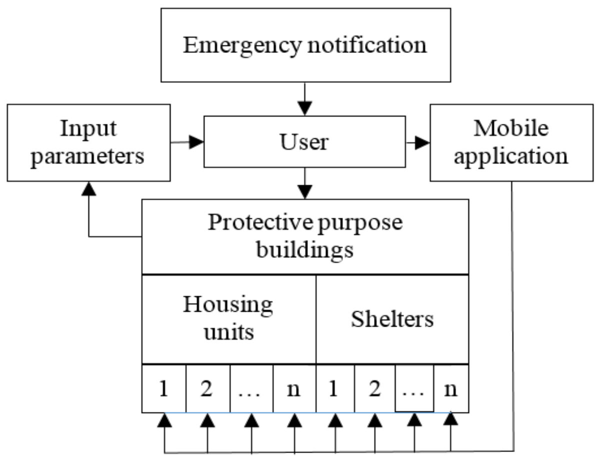


Fig. 1. Flowchart of necessary protective purpose buildings choosing process

If emergency situation will appear and it will be necessary to use protective building or air raid shelter, user should know in advance all important data, including comfortableness level and safety stay in it.

The main requirements that applies to protective buildings and shelters are regulated by the relevant state documents and the Civil Protection Code of Ukraine. These documents specify the external and internal parameters of the protective buildings. External includes geographical location and distance from neighboring homes, and internal includes buildings configuration and planning of elements for safe staying users indoors. However, it is also important for users to have actual information about such buildings.

II. PROBLEM STATEMEN

Review of recent international research shows numbers of existing developments in the fire safety field, particularly about uses of information technologies to improve human's life safety. The whole process of modeling protective environment in buildings for different purpose, including shelters has been describing in detail by scientists. In [1] were explored some aspects and approaches for creation of user-oriented mobile information technologies. This software is developing for individual use to help people in choosing suitable fire protective building where they could hide during emergency situation. According to [2], authors had analyzed fire safety requirements to information technology for implementation in selected commercial building. The main practical requirements to information technologies for fire safety providing in different types of buildings are highlighted and analyzed in [3, 4, 5].

Researches [6 - 10] refer to evaluation system of building fire emergency response capability maturity (FE-CMM) that based on the capability maturity model (CMM). Mostly they are considering to acceptable ways for emergency situations response. Authors declared that the proposed module could preliminarily realize the intelligent evaluation of building fire emergency response capability. Also, it able to improve the practice and intelligence of the fire emergency response capability evaluation, especially in smart cities. Studies [10-12] analyze the main features of developing, improvement and uses of modern information technologies in the field of civil protection, particularly during implementation of safety-oriented emergency response projects.

However, there are still little number of studies that related to software development for protective buildings safety evaluation, as well as for situation comparing capability in different buildings during best option choosing process. Today, there are also not enough information about qualitative evaluation of information technology impact to decision making process of choosing particular building type.

Current state regulatory documents determine all requirements to protective structures, buildings and shelters arrangement, particularly, from the point of safe stay in them. But, due to requirements universality and generality, shelters are objectively limited in ability of getting attention to each ones. The reason of it – lack of a real possibility to create completely safe building for a long stay. As a result, people must make choice of protective building and carry out its arrangement by themselves. This will be possible only if the following conditions will meet:

- the choice of each protective building or shelter is based both on its level of comfortableness and fire protection;
- all possible ways of getting to the protective building or shelter are analyzed depending on humans' location during an emergency;
- information technologies are used as a helping tool to make choice of protective building;
- preliminary prediction is made to determine unforeseen occasions appearance possibility during humans' stay in shelter;
- it is possible to make own additions to the contingency plan.

Therefore, according to previously outlined problems, developing of graphic information technology for fire safety evaluation of protective purpose buildings is one of the most important and urgent task in nowadays moving world.

III. SUBSTANTIATION OF DATA VISUALIZATION METHODS USE IN PROTECTIVE BUILDINGS FIRE SAFETY EVALUATION PROCESS

In general, users informational content I about protective buildings or shelters include two components: visual (presence component) and virtual (technological component) object review. Some users can get necessary information directly by observing selected object without using any information technology (IT), while others can use special software. Bases on this and according to [10], informational content I could be determine by the following equation:

$$I=u+iv=(x+iy)^3 \quad (1)$$

where u, v – components of information content, respectively, without and with the use of information technology; x – presence component parameter that indicate the level of knowledge about object without using IT; y – technological component parameter that indicate the level of knowledge about object with using IT.

Parameter y also takes into account both the level x' of knowledge about the object(building) and the use of developed application f:

$$y=x'+f \quad (2)$$

In most cases, x' does not always equate to x, but for simplifying research, we accept that $x = x'$. According to this, (1) takes the following form:

$$I=u+iv=x((4x^2+6xf+3f^2)+i(x^2-3f^2)) \quad (3)$$

The working range of variables x and f in information content I level determining process is in diapason between 0 and 1. Equation (3) determine information contents value I as a direct numerical dependence to the parameter x: for each level of information support f, the value of information content is equal to zero if $x = 0$. As a result, information content components u and v defines function of x and f. Thus, if we take these conditions into account, components values will determine like (4) and (5):

$$u=4x^2+6xf+3xf^2 \quad (4)$$

$$v=x^3-3xf^2 \quad (5)$$

If user does not use software for help in choosing suitable shelter and condition (2) is fulfilled, the value of components u and v will determine (6) and (7):

$$u=4x^3 \quad (6)$$

$$v=x^3 \quad (7)$$

Component v has value change restriction (8) of x and f. In our research we use only positive values that fits condition $x>3f = a$ and belongs to zone A (Fig. 2).

$$v=x(x^2-3f^2)= x(x-\sqrt{3} f)(x+\sqrt{3} f) \quad (8)$$

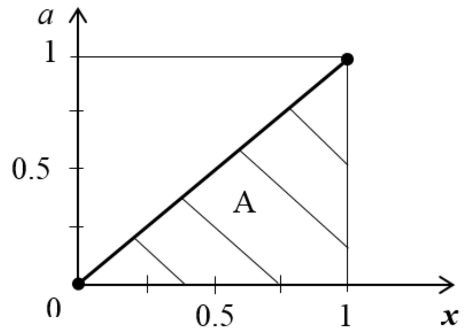
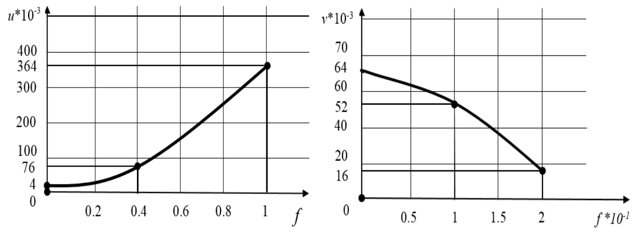


Fig. 2. Restriction zones of parameters

Now, let we determine the influence of parameters x and f to component u (4) values change. Even if x gets small values, such as $x = 0.1$, the values of component u increases extremely fast (Fig. 3 a). This proves the efficiency of using information technologies f.



a b

Fig. 3. Dynamics of components u (a) and v (b) values change

The information contents' component v is determined by the amount of knowledge set ($x'= x$) about buildings fire safety state according to which IT is used for help. The main condition that applies to v it is $x'= x >\sqrt{3f}$ (Fig. 3 b).

IV. Development process of information graphic technology for protective purpose buildings safety level determining.

Information technologies and its use in the field of Civil Defense can solve problem of visualizing data about protective purpose buildings. Basically, proposed emulator will work with graphical parameters of the buildings, which are used during its floors plan creation. Also, there will be possibility add another data, such as temperature of the shelter environment, the presence of fire extinguishers, etc. (Fig. 4).

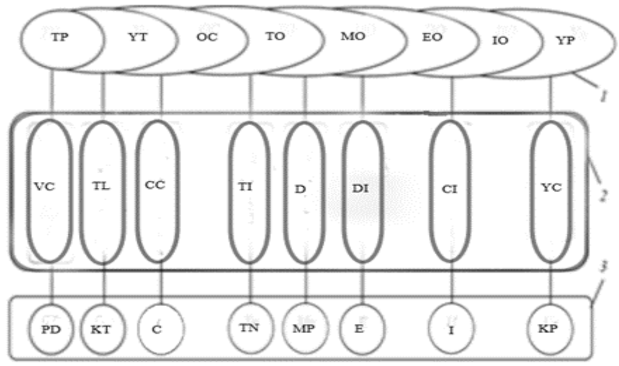


Fig. 4. Information model of data visualization process about protective purpose buildings with use of emulator

where 1 – emulator software operation block: TP - the technological process of emulator creation; YT - control units; OC - provision by programmers; TO - the level of equipment provision; MO - material resources; EO - energy resources; IO - the financial value of technology; YP - software resources; 2 - functional parameters of providing data visualization processes: VC - emulator implementation environment; TL - involved information technologies to the emulator creation process ; CC - the level of performers provision; TI - the level of information provision; D - the level of GPS monitoring technologies involvement of ; DI - the level of easy getting to the building; CI - transport infrastructure near buildings location; YC - basic standards for program creation; 3 - visualization resources: PD - the output product of emulator ; KT - programmers team; C - the product of created program; TN - technical means; MP - material resources; E - energy resources; I - information resources; KP - IT project team.

Information graphic technology is designed as an emulator program “Fireware Emulator”. For its development were chosen Java. “Fireware Emulator” allows users to evaluate protective buildings or shelters safety level.

Java is an object oriented language which gives a clear structure to programs. There are some major advantages of this language. Java is straightforward to use, write, compile, debug, and learn than alternative programming languages. Object oriented programming is associated with concepts like class, object, inheritance, etc. which allows you to create modular programs and reusable code. Java code runs on any machine that doesn’t need any special software to be installed. Those advantages are essential in developing secure, powerful device or computer system that gives you possibility for quick use of the right class and method. Software emulator “Fireware Emulator” was developed using Intellij IDEA 2019.1 Community Edition.

A flowchart of proposed software development stages was designed to facilitate the process of its programming (Fig. 5). The emulator has friendly user interface, is quite reliable and provides high speed of safety evaluate algorithm calculation.

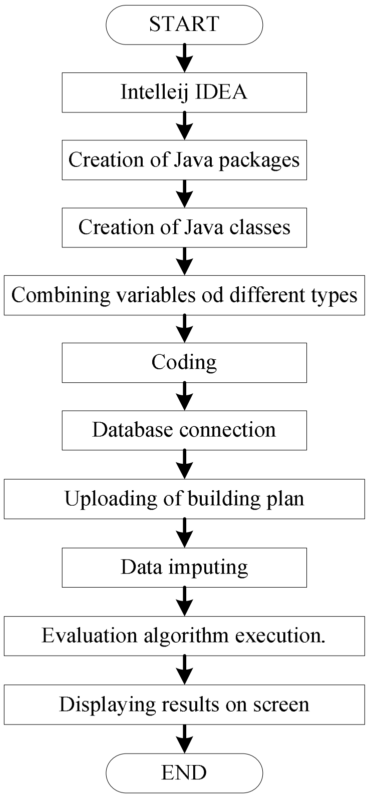


Fig. 5. The flowchart of the "Fireware Emulator" development process

Designed information graphic technology as an emulator program allows users evaluate the security level of shelters independently. The software supports different types of protective buildings and their plans. An algorithm for the process of choosing a safe building is presented in Fig. 6.

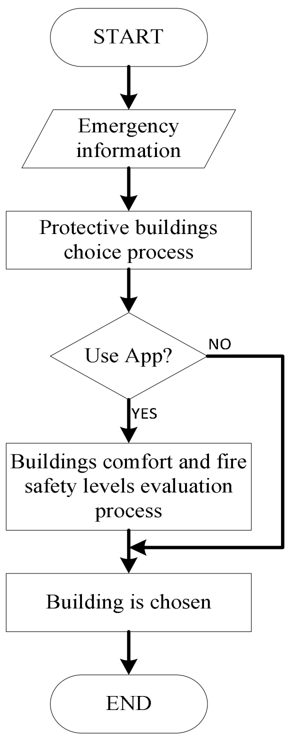


Fig. 6. The flowchart of protective building choosing process

User obtain actual information about buildings fire safety level and can check its reliability and evaluate his own protection in emergencies. This is possible by integrating buildings plan into emulator's database.

When buildings or shelters plans are importing into software database, the following parameters must be specified: inner temperature, height and width of the room, a wall material, the number of persons who may present at the same time. Lighting and air filtration settings are also available. Based on all this data, the program makes analyze and outputs the result of security level evaluation.

Software adaptation to the real conditions of the shelters and protective buildings is provided by changes of their plans. They are made based on additional perimeter measurements. Emulator "Fireware Emulator" stores visualized data of plan in its database, that makes them acceptable for changes up to different conditions.

The emulator interface for the school building is shown in Figure 7.

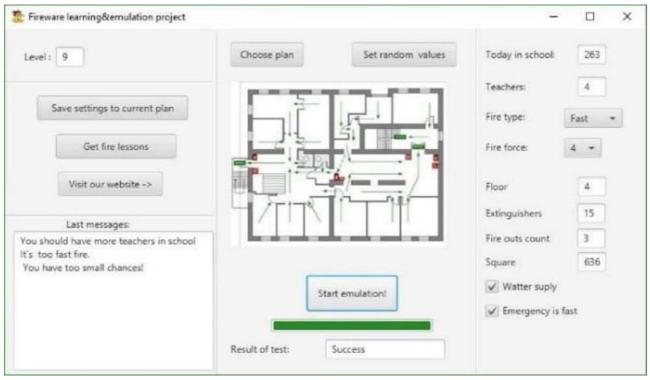


Fig. 7. Initial parameters values setting in software"Fireware Emulator"

Input parameters: two hundred sixty-three students and four teachers will be staying in building at the same time and each of them had passed a fire safety courses; there are four floors, three emergency exits and fifteen fire extinguishers; all-day water supply.

Developed software is open for updates. There is an opportunity to quickly add plans of buildings, functionality, providing reliability, accessibility and multiplatform. A high level of protection against unauthorized changes to the code was used.

V. USES OF DEVELOPED SOFTWARE IN FIRE SAFETY EVALUATION PROCESS

Next stage of research is analyzing correctness of the software algorithms. There were 4 practical experiments conducted using different input parameters, protective building plans and squares.

Experiment 1. Input parameters used in experiment: storage temperature - 21 °C, height - 2.45 m, width - 4.35 m, wall material - metal construction, number of persons - 5. The result of emulation (Fig. 8) demonstrates that such protective building complies to all standards and regulations and is completely safe to stay in an emergency.

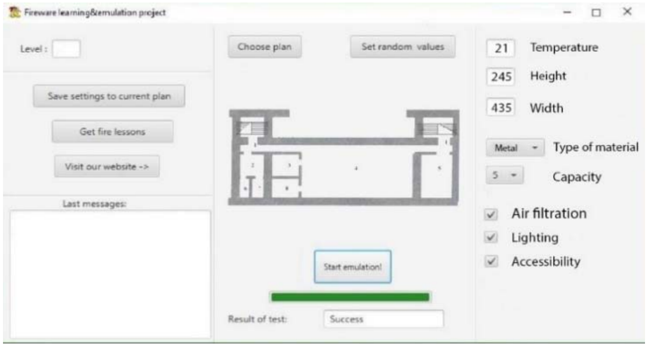


Fig. 8. Experiment 1: result of "Fireware Emulator" running with imput paramemters

The program provides a large number of parameter combinations. The algorithm selects the most optimal by analysing of given data [10]. In case of inconsistency, the program produces a negative result.

Experiment 2. Were used parameters which did not complies to standards or regulatory documents. Due to input parameters this shelter is uncomfortable for staying and the result of fire safety evaluation is negative (Fig. 9).

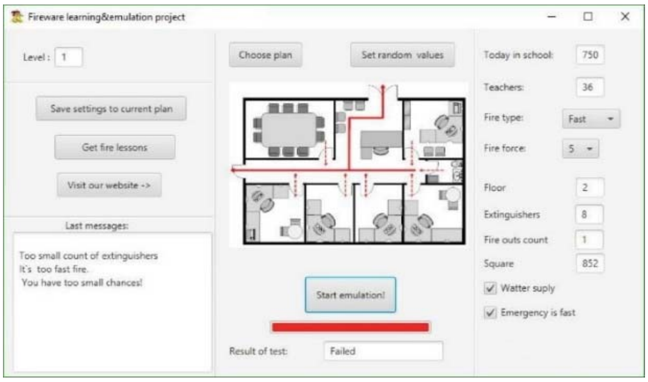


Fig. 9. Experiment 2: the result of buildings fire safety evaluation with many people inside

This is because there is no ability to avoid the danger: the building has a large square and only one spare exit, the number of people is too big, the fire ignites quickly and there are only eight fire extinguishers.

Experiment 3. A shelter with small square were analysed. Also there were a low wall height and inside temperature (8 ° C), the number of staying persons - 6. According to the normative documents, such protective building is not suitable for a comfortable staying despite positive level of fire safety evaluation. The result of the program demonstrates a similar conclusion (Fig. 10).

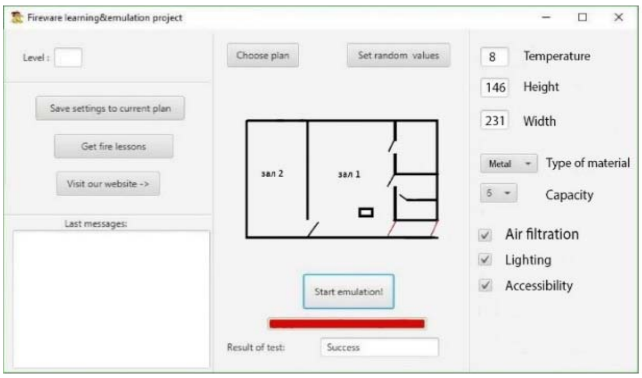


Fig. 10. Experiment 3: negative result of shelter staying comfortability

Experiment 4. In developed software "Fireware Emulator" is predicted a graphic information window for displaying problems which must be solved to increase both fire safety and comfortability levels. In Fig. 11. is presented the result of evaluation process, according to the input parameters. In information window is displayed text message with recommendations.

Analyses of input conditions and received recommendations (Fig. 11) shows that the algorithm of message output is correct. The inside temperature of 4 degrees above zero storage does not correspond to the norm, the height - 1.68 m and the width - 4.61 m. In this experiment, there is lighting, but no air filtration. All this conditions are dangerous and not comfortable for staying of 52 people in shelter.

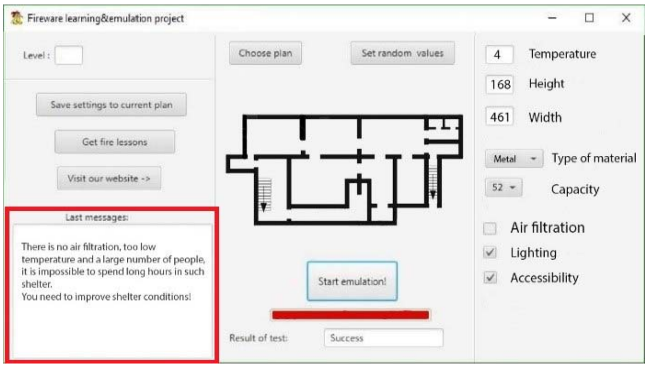


Fig. 11. The result of evaluation process with generated recommendations

The errors and deviations of the program are minimal, and their analysis indicates correctively of algorithms calculations.

VI. Conclusion

Current rates of science and technology development, integration of information technologies into everyday life of society, state of ecology and influence of anthropogenic factor on the environment lead to appearance of new emergencies. The ability to make the right decisions in such circumstances is a guarantee of safety human's life. That is why it is so important for human today to have as much as possible information about around environment.

Informational graphic technology was developed as an emulator program to help people in process of protective buildings fire safety level evaluation. The emulator program "Fireware Emulator" is a product of universal purpose. It helps to determine the level of person's security staying in protective purpose buildings. Developed software is designed for personal use. Performance of the program can be enhanced by the combination of prior knowledge about object and the information component comparing. Also were made mathematical substantiation of evaluation algorithms execution correctness.

Integration of the latest information technologies in the field of civil protection will provide to society an effective tool for analyzing and using data to explore possible ways of avoiding or protecting against emergencies.

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