International Journal of Multidisciplinary Research and Growth Evaluation.

Fire Management Logistic System Model, accidents and natural disasters

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Article Info

ISSN (online): 2582-7138
Volume: 05
Issue: 03
May-June 2024
Received: 10-03-2024
Accepted: 13-04-2024
Page No: 304-311

Abstract
This article is the second part of a complex scientific study aimed at analyzing all components in the process of protecting the population from disasters and accidents and proposing a logistic system aimed at improving the response and effectiveness of the actions of the services responsible for this protection. More specifically, we focused on fires and firefighting, as a key factor in environmental protection.
The system analysis carried out, described in detail in the first article, gives us the basis to draw conclusions and findings on the basis of which to define the main elements of the logistics system and to propose a new one, the subject of the present work. As a result of the research, a model of a logistics system for action in case of fires and disasters is proposed.

Keywords: fires, general engineering, logistics systems

1. Introduction

Every year, fires lead to the loss of hundreds of thousands of hectares of forests with high costs for extinguishing them, accompanied by the loss of a number of functions of the forest and even the loss of human life. The consequences of fires can be grouped into the following main areas:

- Ecological - defined by deforestation and soil erosion, as well as by changes in water flow, disruption of the heat and water balance of ecosystems. Destruction of unique habitats of rare, protected species, limitation of biological diversity. Deterioration of the sanitary condition of forests and reduction of CO_2 absorption capacity;
- Economic - determined by the wastage of forest resources after many years of wood investment. Extraordinary allocation of funds to limit harmful consequences. Reduction of land productivity and deterioration of growing conditions. Reduction of revenues from timber extraction for industry;
- Social - determined by deterioration of the microclimate and conditions for economic activity, decline in the tourist business. Limitation of livelihood opportunities and impoverishment of the population. Depopulation of areas and fire-hazardous settlements.

In recent years, fires have caused enormous material damage and have become a serious disaster for our country. They occur in different places (forests, populated areas, etc.), and are identified by the presence of flames, smoke, falling soot, unusual odors, and the behavior of animals. Extinguishing fires is organized and carried out by the forces of the Main Directorate "Fire Safety and Protection of the Population" of the Ministry of Internal Affairs, the Ministry of Agriculture and Food, forces of the Ministry of Defense, NGOs and volunteer groups from municipalities and town halls. The factors that have a significant impact are the wind, the infrastructure, the place or area of action, the technical equipment, the organization of interaction, etc., related to various disaster situations. Summarizing the analysis, the increase in fires is the result of two main factors:

1. Climate changes aggravated by anthropogenic activity;
2. Human intervention – fires caused by deliberate arson or negligence.

This raises a number of questions related to the mitigation and control we can exercise to prevent the worsening fire problem in Bulgaria and the Balkan Peninsula.
One of these issues is the creation (optimization) of a logistical system for the organization and management of firefighting activities, its organizational, technical, technological and economic characteristics in compliance with the European standard norms for risk assessment and protection of the population from the created undesirable consequences.

2. Research methods

They include a study of the dynamic processes of fires, disasters and accidents substantiated by logistic management systems by the structures of the Ministry of Internal Affairs and administrative structures. Optimizing the work of management bodies and risk assessment in compliance with European and Bulgarian standards and laws. Application of modern technologies in the evaluation of the technical operation of machines and equipment used for extinguishing fires, accidents and natural disasters. Modeling of the technological characteristics of the logistics system for risk management and organization and offering a methodology for assessment and prevention in protection against fires, accidents and natural disasters.

3. Exposure

3.1. Designing the structural characteristics of logistics systems for the assessment of technical operation.

The development and incorporation of the main evaluation factors of a given process is carried out on the basis of the idea of endless and dynamic change of accepted and systematized indicators and criteria. This gives us reason to adopt the following sequence: study (study) → planning (plan) → implementation (do) → control (check) → evaluation and corrective action (evaluate). The content of the research stage (S) includes the study of the processes and the definition of the main guidelines related to the technical operation and the role of the human factor. The planning stage (P) is aimed at determining the activities for the prevention of "events" (by this term we understand fires, accidents and natural disasters) and developing modules for organization and management by state structures and non-governmental organizations. The system evenly loads the two stages of execution (D) and control (C), which check to what extent the set goals have been achieved. At the stage of corrective action and evaluation (E), the performance of the set tasks is taken into account. The successful implementation of the stages defining the system are a prerequisite for adapting the requirements for limiting the impacts in all their forms, as well as regulating the powers of the institutions to the relevant responsibilities and obligations. This basic approach is coordinated with the infinite dynamics model of eight priority principles [2]:

- General institutional and individual binding of the goals for the prevention of events with the moral and ethical values of society;
- Closely approaching the structures of the state and public structures and more precisely defining their activities, with the aim of training the security authorities in this direction;
- Planning the implementation of all activities related to overcoming the after-effect of one or another event;
- Adopting standards for evaluating the level of management and determining the authority of the institutions and the level of performance.
- Introduction of a process of improving the organization and management of prevention to prevent events of all levels and forms.
- Measuring the levels of events and creating a unified assessment regime of socio-economic indicators and the role of society.
- Requirements for continuous improvement of preventive measures related to the evaluation of events.
- Validation of the results of the activities of the legislative, executive and judicial authorities.

Therefore, the adopted logistics management system is based on three main criteria: definition of factors and parameters, selection of evaluation criteria and structure of state institutions related to population protection. These three criteria are accepted as a basis for evaluating the institutions and their role in guaranteeing the security of citizens in the country. Event priming is a process of goal-directed influence that targets the target function of behavior. The main elements for such a system to function are:

- Subject of management - develops and realizes the management impact;
- Object of management - the managed process, activity, organization, structure, business, etc., and in a functional aspect there must be an interrelationship of three things - input, process and output;
- Rights and connections - through them the subordination and the impact on the system are realized;
- Feedback – it controls the operation of each stage of the system;
- Surrounding (environmental) environment – everything that is considered to be factors affecting the object and the subject of management.

Analysis of the structure gives us reason to adopt the standard management approach consisting of [2]:

- Psychological control – regulating, leading, directing, forcing: the object is a person or people whose character is automatic, i.e. accept primary commands and perform instinctive actions;
- Social management – both the subject and the object are social elements and their relationships are managed;
- Financial management – cash flows are managed to eliminate impacts and restore damaged infrastructure.

The role of state and public structures for prevention continues to be high, depending on the means used. Any structure for the protection of the population is a complex organized system and is defined as "consciously coordinated activities of the community". In order for coordinated activities to take place, the following requirements must be met: there must be at least one goal (ie, a desired end state or outcome) that is accepted by community members; members to work together with the intention of reaching the all-important goal. This type of complex (modern, modern) organizations also have other common characteristics:

- Resources – people, capital, materials, technology and information;
- Dependence on the external environment – suppliers, laws and government bodies, consumers, competitors,

technology, economic conditions;
- Dependence on the internal environment – strategy, goals, structure, tasks, technology, people, corporate interests, etc.;
- Horizontal and vertical division of labor.

The theory of management of these activities confirms that a manager can directly manage a group of people, which depends on his place in the hierarchical structure, the classification of events, the nature of the functions performed in the organization. In every organization for the protection of the population, there are three types of management relationships [2]:
- Linear Relationships - express the subordination of management, they are regulated, mandatory, vertical, command.
- Functional - clearly regulated and mandatory rules and regulations.
- Cooperation - unregulated, optional and other types of relations based on informal relations.

The main types of event management structures are:
Linear management structure - all management activities are performed by one person. Main advantages are: precise distinction of rights and responsibilities; reliable communications; suitable for solving routine tasks; simple and clear links between management levels; quick decision-making capabilities. Disadvantages: the contractors are overloaded and find it difficult to perform the activities; danger of a risk to human health; governing bodies are not able and cannot solve all problems; difficult adaptation to new tasks and responsibilities; there are no opportunities for development; lack of coordination opportunities.
Functional structure - there is a functional head who manages all units, but only within his function. There is a division of managerial labor. Advantages: management competence increases due to the better intellectual level of the manager; better distribution of financial flows; opportunities for specialization and qualification in a given direction; cover all functions of socio-economic life. Disadvantages: the unity of disposition is violated; lack of clearly demarcated responsibility and greater freedom of action; complex connections and poor coordination in interaction.

A line-functional structure combines elements from the previous ones, with the created functional units served by line managers. Advantages: the quality of the decisions made increases, because it is not made by just one opinion, but is prepared by a leadership circle; the work of line managers is facilitated; a large part of the activity is undertaken by organizers specialized in a given direction. Disadvantages: the process of making management decisions is delayed; there is a danger of excessive growth of management units.
The study of the logistics system, as an element of the national security system, must meet four conditions:
- To consider event-related phenomena and properties, united in a system, and not to be analyzed fragmented and chaotic;
- To consider the events as a process studying the development over time and based on its momentary state;
- To look for logic in all actions, connections and relations on which the system functions;
- To introduce a certain degree of abstraction, i.e. separating the essential from the non-essential, breaking away from the empirical and the concrete in order to build logical connections to and draw upon ideas from other areas of knowledge.

The nature of the issues requires that we consider them in relation to the risks and threats to the individual. In this way, they can be economic, social, demographic, informational and many others. This gives us reason to consider civil protection as a complex social system and means to perceive the processes and phenomena that make it up in unity, overall interconnectedness and contradiction. Such complex systems obey general laws that express the most essential connections and relations between the components of the system itself and between it and the environment. Systemology requires a sufficiently deep assessment of behavior and properties, and this necessitates the study of its functional characteristics: efficiency, reliability, manageability, robustness and complexity. In the prevention system, there are three objects of security: the individual, the society and the state. The proposed approach is one of the first attempts to analyze the problem of protecting the population from fires, accidents and natural disasters, proposing the following structural scheme (Figure 1):

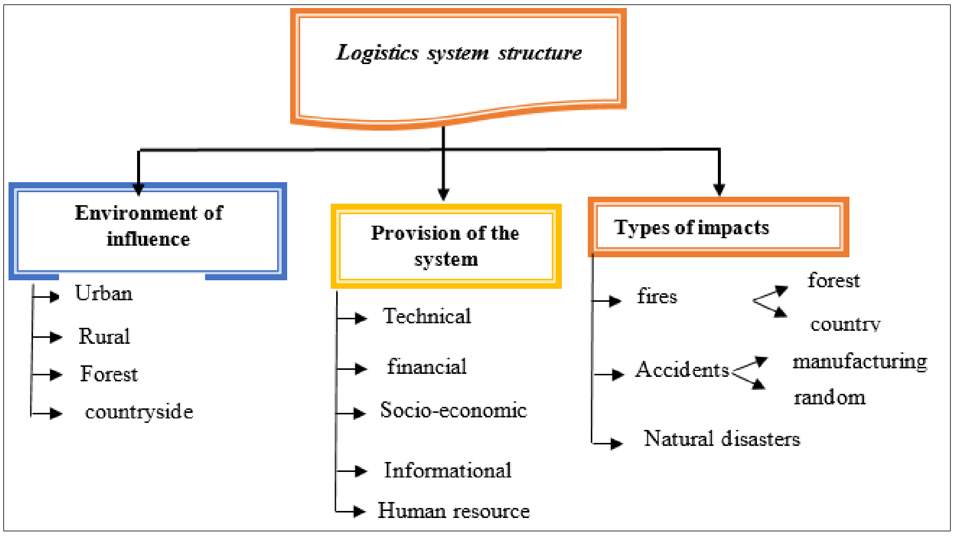

Fig 1: Structure of a logistics system for the management of fires, accidents and natural disasters

Analysis of Fig. 1 provides us with information on the entire set of activities that are provided by the state institutions of the Ministry of Internal Affairs, Ministry of Defense, regional and municipal administration. At the same time, the security of the state means the presence of an effective mechanism for managing and coordinating public groups and political forces, as well as effective institutions for their protection. For this reason, the subject of the research focuses on the structure and organization of the logistics system. On this basis, we formulate the parameters of the individual impacts: time t [min]; propagation speed v [m/hour]; distribution area s [dec.]; frequency of occurrence h [min] and action interval i [hour]. Each one of these parameters is characterized by its variables and participates in the probability of occurrence of the given event. The object of logistic research is to overcome impacts. For each observation of a given event, the necessary information is collected (statistical data on fires for a one-year period) [3]. On the basis of the proposed structural determination of the logistics system and the complex economic and social changes related to overcoming the impacts, as well as the results of growth of the fire situation and a sharp drop in the standard of living, civil protection takes on a new essence. Specialized studies [4, 5] indicate that the consequences of changes have led to a large number of people treating state and municipal property irresponsibly. There are not a few cases when regional and municipal structures postpone or do not pay the necessary attention to objects threatened by accidents and natural disasters.
The data show a remarkable similarity between fires and natural disasters, which is why they are presented together. Accidents and catastrophes differ only in the place where specific characteristics determined by qualifications and accumulated professional experience are present. This type of event, from the point of view of its social characteristics, occupies the lowest level in the socio-economic sphere. At the same time, this is the most obvious form of impact, which is why most of the offenders caught in fire actions are illiterate or irresponsible when handling fire. Usually the offenders are of low social status, mostly of Roma origin. They work around the clearings of large forest massifs, ring roads and the outskirts of settlements [14].

3.2. Determining the volume of the computational procedure

Each event is characterized by many different signs, which is a large amount of information. This gives us reason to accept the time, as an indicator consisting of: time for submitting information to telephone number 112 - tn; information time of the fire service - tsl.; arrival time at the extinguishing site - tpo.; time to neutralize the fire - tgas.; time for damage assessment - tdamage. and time to return to the unit - tkr.. The engineering research plan contains a set of data determining the total response time of the system and the quality of the information. We present the changes in the times of three objects from the statistical information bulletin of the Ministry of the Interior in the following sequence [6, 7]:

- First measurement of the time from the message to the fire department of the regional center;
- A second measurement of the time from the unit to the occurrence of the event, including the deployment of the equipment;
- Third level fire extinguishing, its localization and completion of all operations;
- The fourth level is related to the assessment of the damage and the risk of striking the teams and people affected by the fire.

The evaluation times are taken for fires in populated areas A, forest B and field C, and for each of the cases we have $t_{\Sigma} = t_{н} + t_{sl.} + t_{по.} + t_{gas.} + t_{sht.}$. For each of the sites respectively t_A, t_B and t_C we examine each parameter for the objects:
$t_A, = x_1 - x_0$; $t_B = x_2 - x_0$; $t_C = x_3 – x_0$, and the variance for each species is [8]:

$$\sigma_A = \sigma_{x_1}^2 + \sigma_{x_0}^2 = 2\sigma^2 \quad \left(if\ \sigma_{x_1}^2 = \sigma_{x_0}^2 \right) \tag{3.1}$$

$$\sigma_B = \sigma_{x_2}^2 + \sigma_{x_0}^2 = 2\sigma^2 \left(if\ \sigma_{x_2}^2 = \sigma_{x_0}^2 \right) \tag{3.2}$$

$$\sigma_C = \sigma_{x_3}^2 + \sigma_{x_0}^2 = 2\sigma^2 \quad \left(if\ \sigma_{x_3}^2 = \sigma_{x_0}^2 \right) \tag{3.3}$$

The experiment matrix has the form:

$$\left| \begin{array}{l} t_A = \frac{1}{2}(x_1 - x_2 - x_3 + x_4) \\ t_B = \frac{1}{2}(x_2 - x_1 - x_3 + x_4) \\ t_C = \frac{1}{2}(x_3 - x_1 - x_2 + x_4) \end{array} \right. \tag{3.4}$$

The time of object A determined by the formula is not affected by the time of objects B and C, since each of them participates in the formula twice with a different sign. The variance associated with the timing error is given by:

$$\left| \begin{array}{l} \sigma_A^2 = \frac{1}{4}\left(\sigma_{x_1}^2 + \sigma_{x_2}^2 + \sigma_{x_3}^2 + \sigma_{x_4}^2\right) = \sigma^2 \\ \sigma_B^2 = \frac{1}{4}\left(\sigma_{y_1}^2 + \sigma_{y_2}^2 + \sigma_{y_3}^2 + \sigma_{y_4}^2\right) = \sigma^2 \\ \sigma_C^2 = \frac{1}{4}\left(\sigma_{z_1}^2 + \sigma_{z_2}^2 + \sigma_{z_3}^2 + \sigma_{z_4}^2\right) = \sigma^2 \end{array} \right. \tag{3.5}$$

We take the fixed values of the factors as levels at which measurement is performed, and the logistic activities are set with a matrix of the conditions of the passive experiment. The form of this matrix for k factors and m statistics is:

$$x = \left| \begin{array}{llll} x_{11} & x_{12} & x_{13} \ldots x_{k1} \\ x_{21} & x_{22} & x_{23} \ldots x_{k2} \\ \ldots\ldots\ldots & & & \\ x_{1m} & x_{2m} & x_{3m} \ldots x_{km} \end{array} \right| \tag{3.6}$$

The values of the impacts obtained during the extinguishing of the fire, as well as all the engineering equipment, we also present in a matrix form:

$$y = \left| \begin{array}{llll} y_{11} & y_{12} & y_{13} \ldots y_{n1} \\ y_{21} & y_{22} & y_{23} \ldots y_{n2} \\ \ldots\ldots\ldots & & & \\ y_{1m} & y_{2m} & y_{3m} \ldots y_{nm} \end{array} \right| \tag{3.7}$$

Using statistics from fire situation analyzes greatly changes factors (wind speed, terrain type, engineering equipment, number of personnel, etc.) and maintains them at the time level. Therefore, this requires the control factors to take into account the following requirements: controllability of the factors - the ability to maintain certain levels characterizing the fire situation for a certain time; sufficient engineering equipment to control the level of the factors without increasing their values; independence of individual factors from weather conditions or other factors related to fire extinguishing; compatibility of factors ensuring personnel safety and the possibility of risk assessment at all levels of impact. We express the levels of the factors with their numerical values, but they can also be expressed quantitatively, by coding the type of fire (in a populated place, forest and field terrain) A, B and C. We process the statistical data by converting it into dimensionless quantities and, if possible we round to whole values using the formula [9]:

$$x_{ij} = \frac{(X_{ij} - \overline{X_j})}{\Delta X_i}, \qquad (3.8)$$

Where: x_{ij} – conversion of the j-th factor for the i-th level; Xij – natural value of the i-th level for the j-th factor; ΔXi – constant interval of change of the value of the j-th factor; r - number of factors

$$\bar{x}_j = \frac{1}{r}\sum X_{ij} \qquad (3.9)$$

Analysis of the accident in the village of Hitrino with factors j there are r = 5 levels with values 8, 12.9, 17.9, 22.6, 25.7 with a step ΔXi = 5, then the converted values x_{1j} =(4.8-12.9)/5 = -1.62 ≈ -2; x_{2j} = -1; x_{3j} = 0; x_{4j} =1; x_{5j} = 2. To perform the transformations we use the dependence [9]:

$$\bar{x}_{ij} = 1 + \frac{X_{ij} - X_{i\,\min}}{\Delta X_j} \qquad (3.10)$$

Where: Xjmin is the minimum level of factors influencing the intensity of the fire.

This basically means that the metric values validate the damage caused by the assumed factors. Therefore, the analysis of the dependence (3.10) shows the minimum necessary number of factors for a polynomial of the first degree, which means no less than two. The full evaluation of the statistical analysis is realized by factors whose levels are within the limits of m = 2k, at levels (+1 ÷ -1). In practice, there are other evaluation methods, but we adopt this one because it allows to approach each specific factor of the given reality. For each particular case, we apply the equation of the form [10]

$$y = a_0 + \sum_{i=1}^{3} a_i x_i + \sum_{in=1}^{3} a_{in} x_i x_n + a_{1,2,3} x_1 x_2 x_3 \qquad (3.11)$$

Analysis of the expression (3.11) shows that the important parameters of the accepted factors for the activity of the fire situation are, respectively, the mathematical expectation M of the random factors grouped for each type of fire and the dispersion σ^2 characterizing the degree of activity of the random variables determined by the dependencies:

$$M = \int_{-\infty}^{+\infty} x f(x) dx \qquad (3.12)$$

$$\sigma^2 = \int_{-\infty}^{+\infty} (x - M)^2 f(x) dx \qquad (3.13)$$

Besides the mathematical expectation for the characteristics of the factors, we can use the mode M_0 (value of the random variables influencing the intensity of the fire) and the median Me (value of the random variable equal to ½ of the area under the curve of the distribution density). The distribution function F(x) and the corresponding density f(x) represent the mathematical model of the investigated random variables. Therefore, the main task of the research is to find such kind of value parameters that describe the variable quantities and are convenient for statistical analysis. Therefore, to process the experimental data, we use the normal (Gaussian) distribution, which states "under certain conditions, the distribution of n independent random variables is a random distribution and tends to the normal when n→∞" [11]. We make the necessary condition that individual random variables have a finite variance no larger than the others. This means for the accepted random variables to form results from the influence of a large number of uncontrollable factors according to the dependencies [12]:

$$n = \frac{z^2 s^2}{E^2} \quad or \quad n = \frac{z^2 p(1-p)}{E^2} \qquad (3.14)$$

where: z – guarantee multiplier of the variable factors; s2 – the variance of the studied characteristics equal to s = p(1 - p); p – are the errors from the actual values of the variables; E – maximum stochastic error.

$$n = \frac{z^2 s^2 N}{E^2 N + z^2 s^2} \quad or \quad n = \frac{z^2 p(1-p) N}{E^2 N + z^2 p(1-p)} \qquad (3.15)$$

When working with variational features, it is possible to estimate the mean or total value in the population based on the use of a statistical sample. In order to facilitate the calculation procedure, the formulas used are implemented in a spreadsheet environment (MS Excel). From a theoretical point of view, the modeling should be based on the normative documents regulating each activity. The main parameters involved in the model are: the technical characteristics of the machines and equipment determining their working efficiency; the basic efficiency of transport, load-lifting and specialized equipment depending on the activities that are carried out in the field; the parameters of the equipment and the equipment necessary for the work of the teams, according to the specific situation; to define the evaluation criteria when drawing up the program of the system for organization and management of impacts; assess the threats and vulnerability of the personnel in the repair of the damage and adopt the risk assessment methodology. In the case of irreversible selection or a small volume of the general population, it has the form presented in table 3.1.

Table 1: Procedure for calculating the volume of variable quantities

№	Type of fire variables	Calculation of variables					
		z	*p*	*E*	*s*	*σ*	*n*
1	Urban	0,86	0,03	0,02	0,09	14%	28
2	Rural	0,91	0,02	0,01	0,11	21%	31
3	Forest	1,02	0,15	0,32	0,26	80%	186
4	Countryside	0,98	0,14	0,12	0,18	68%	89

The received expert information is analyzed from the point of view of the consistency of the opinions of the experts who participated in the expertise. If the discrepancies are significant, then it makes sense to find out the reason for the discrepancies. Analysis of information begins with the search for possible analogues. And in this case, the information about the relevant reference situation and about the differences established by the analytical group is transmitted to the expert commission for the development of a final conclusion Fig. 3.2.

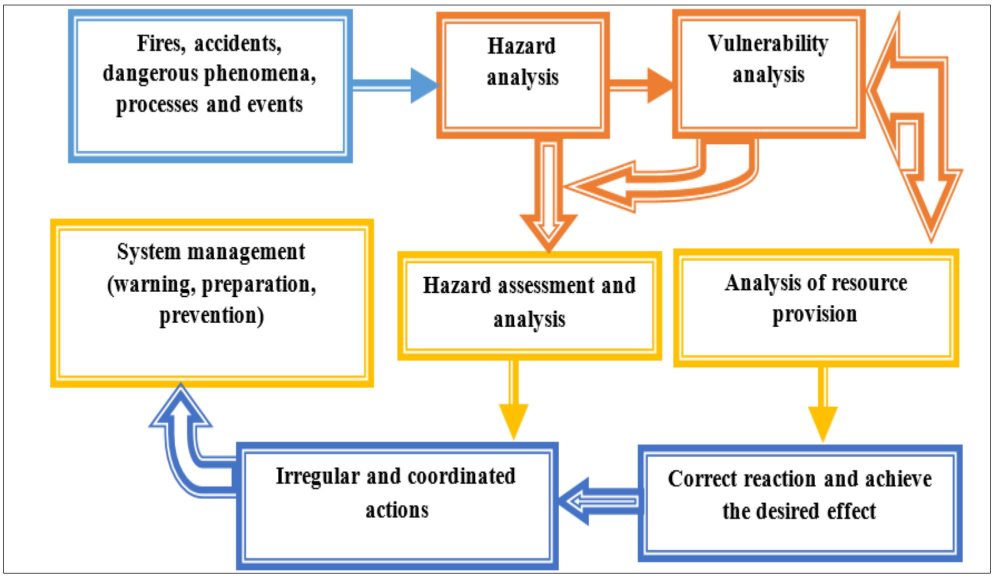

Fig 2: Methodological framework for the functioning of the logistics system

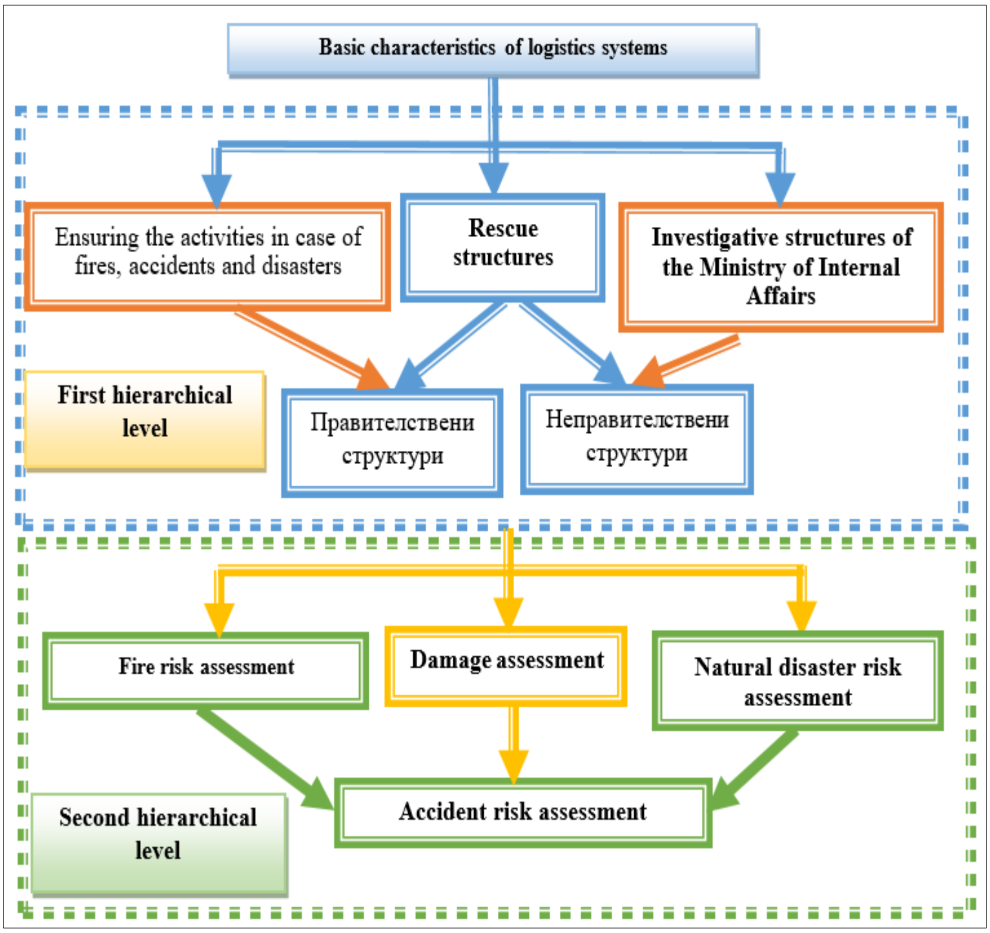

Fig 3: Hierarchical structure of the logistics system

In the bank of situations Fig.3. along with the information about reference situations, information about other situations that happened before can be stored. If the situation that has arisen is one of the reference ones, then one knows how to act in it. Information about analogues is presented in the form of a certain number of reference situations. If the resulting situation is such that it seems close to one of the reference ones, then it is necessary to assess how significant the existing differences are. When a sufficiently large amount of information is found at this stage, it is appropriate to conduct a preliminary review to reject insufficiently meaningful or inaccurate data. Based on the analysis, a package of information is formed, which is necessary for the situational analysis. Preparation of analytical materials based on the results of the situational analysis is to prepare analytical materials containing recommendations in various areas: making strategic and tactical decisions in the analyzed situation; mechanisms for their implementation; control over the implementation of decisions; support for the implementation of the decisions taken; analysis of results, including evaluation of the effectiveness of decisions made and their implementation. The result of the work of the experts at this stage of the situational analysis is the assessment of alternative options for SD obtained during the situational analysis, the determination of recommendations and proposals for decision-makers based on the results of the work performed (Fig. 3.3).The work of organizing and conducting analysis at all stages Fig. 3.3 are methodical and information provision carried out respectively by the analytical and working groups with their assigned tasks and delegated powers. Effective use of such an approach to solving management problems is of particular importance for the organization, which is impossible today without appropriate computer support [13]. The advantage of such an analysis is "immersion" in the situation in order to make the right informed decision. The parametric quantities used help to perform more complex tasks in logistics system management. Through their application, management is combined with the possibilities of modern technologies. The advantage of this approach is greater flexibility in system design and operation, as well as reduced power and complexity for processes that require high speed or high power output. The sequence of work in determining the volume of the sample in the study of a variation sign is as follows:

1. A comprehensive list of all the units of the general population is drawn up, and they must refer to the same period of time and be as uniform as possible, i.e. to refer to the same scheme in on-the-spot checks and to the same refund request in administrative checks.
2. The sign that was examined when performing the administrative checks or on-site checks, which are variations, is determined.
3. The sampling method of random sampling or systematic sampling is chosen.
4. The sample volume with acceptable accuracy E, which is the maximum allowable stochastic error, is determined.

The proposed modeling approach is based on the state of technical operation of the machines and equipment from models and methods for researching the indicators of dynamic characteristics and energy efficiency using adaptive control algorithms.

4. Conclusions

1. The proposed logistics management system is based on three main criteria: time for the impact, damage and risk of the after-action and reasons (factors) for the occurrence of the event. These three criteria are accepted as a basis for evaluating the impact of guaranteeing the security of citizens. The main indicators for evaluating the countermeasures from the events that have occurred are defined and the principles for guiding and managing the security system are justified.
2. The three types of factors for managing the effects of fires, accidents and natural disasters - psychological, social and financial - were prioritized, and the conceptual model of the technical operation system was built on this basis. It is based on a linear-functional structure, which allows to examine the role of the human factor and the technical assurance of the national security system.
3. The laws ensuring the connections and relationships between the components of the fire, accident and natural disaster management system have been adopted. The three components for the security of the person, the society and the state are defined, and on this basis the structural elements of the interaction in the logistics system are derived. A classification of the main operational indicators of the machines and equipment used in the logistics system is proposed for technical evaluation.

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