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Modeling of Fire Traits to Allot Fire Service Resources in the Most Efficient Way Possible

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Abstract: *The essay investigates the connections between the primary factors that influence how fires spread at various facilities that guarantee the fire safety of industrial companies and areas. To support the sufficiency of the fire service's resources and their logical distribution, the modeling of a fire's characteristics during its emergence and extinguishment is taken into account.*

Keywords: *state fire service, models, analytical, simulation, random variable.*

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The results of the studies suggest that a lack of resources for the fire and rescue service, which conducts fire and rescue operations, a wide service area for the state fire service units' regions of departure, and other factors are mostly to blame for the effects of fires. The use of contemporary methods of system analysis of the fire service's issues, the environment in which it operates, including the evaluation of factors characterizing the development of a fire at the facility, operational management of fire service resources in order to increase the efficiency of all components of the fire safety system, makes it possible to find the best solution to these issues.

The completion of the assigned tasks entails the following: identification and analysis of the relationship between the primary factors influencing the growth of a fire at an object, modeling of the characteristics of a fire's growth and extinguishment, efficient allocation of fire service resources, and development of a methodology grounded in science from the perspective of system analysis for evaluating the efficiency of the operational activities of the units of t

The study provides solutions to the following parts of the problem under consideration: the selection and justification of metrics for evaluating industrial buildings and structures' state of the SOPB;

- development of RPO assessment algorithms based on techniques for simulating the temporal aspects of the process of fire and rescue operations;
- the creation of software to track how fire department resources are distributed using a series of linear programming puzzles;
- the creation of a technique for determining how well fire service facilities are operating based on a set of probabilistic issues that are resolved utilizing game modeling techniques.

The task's parameters are a collection of circumstances at industrial facilities, buildings, structures, and geographic areas that influence the likelihood of fires occurring as well as their potential size and effects.

The active adoption of contemporary methods of situational forecasting and resource management in order to enhance the performance of fire service facilities is necessary to address the difficulties of ensuring fire safety at this time.

The process developed in accordance with the law and the charter for drawing the forces and means of the garrison to extinguish fires in the settlement is the attraction of forces and means for suppressing fires, and a schedule of departures is created.

The departure schedule's primary features are:

- Fire number, a conditional indicator of the complexity of the fire, which establishes the necessary composition of the forces and equipment of the garrison participating in putting out the fire in the departure timetable. [1];
- the location where units depart from; - the region where the priority direction of units on a call to a fire is specified in the departure schedule.

The difficulty of fire has three tiers:

First level: The State Fire Service division responding to the fire in the area of origin is involved;

Second level: units of the state fire service are involved in addition to the first level, close to the point of departure of the unit where the fire erupted;

Third level: all combat crew-trained state fire service units of the garrison are involved, and new reserve equipment is added.

The following person is in charge of the unit assigned to respond to fires and accidents in the region of another fire brigade:

- the squad leader upon departing one squad;
- the head of the guard when leaving two or more branches.

The dispatcher may, depending on the circumstances, cover the exit zones of the state fire service units battling the fire.

In reality, it is preferable to employ straightforward techniques for computing fire parameters utilizing current software and information software development tools, on the basis of which mathematical modeling will be done to assess the features of fire growth at the site.

Analytical and simulation models are two categories of mathematical models. A model reflecting the dependency of the temperature of a conventional fire on time, used in assessing the fire resistance of building structures, was one of the first and simplest analytical fire models. It is provided in tabular form or as an empirical formula and is frequently referred to as the standard temperature-time curve. It is frequently spelled out in the literature [3] as:

$$\mathbf{T = T_0 + 345\, lg(8\,x+1)}, \quad (1)$$

here **x** – time, min;

$\mathbf{T_0}$ – initial temperature, °C;

T – current fire temperature, °C.

A series of computer programs called simulation models recreate the algorithms and practices used to explain the characteristics and dynamics of the process under study.

The interaction of the primary fire factors with the environmental parameters over a period of time results in the condition that develops as a fire at an item. It is the total of all the things that should happen or are happening because of the fire. It is feasible to forecast the situation and anticipate its change during the course of the fire development by understanding the laws of fire dynamics.

The concept of a fire's duration and the time it takes to put it out can be interpreted in a variety of ways, but they are all employed in specialized literature one purpose or another. For example, in the study [5] it is proposed to use the relation

$$\tau = N / n, \quad (2)$$

here **N** – amount of combustible substance, kg/m^2;

n – burnout rate of a given substance, kg/(m^{2}h).

In the research [4], he builds a theoretical link between the intensity of the delivery of various fire extinguishing chemicals, their overall consumption, and the duration of combustion cessation in a fire.

Scientific study and fire suppression techniques have demonstrated that the duration of a real fire might range between 2-3 hours. Fires do not last more than 1-1.5 hours in flats, 5-6 hours in basements, and 2-3 hours or more in buildings with a large number of people.

The goal of mathematical modeling of systems is to apply mathematical approaches to solve issues as effectively as possible using, in most cases, contemporary computer technology. When operating under situations of uncertainty and risk, it is best to employ simulation methods as a tool for mathematical modeling. The simulation model is based on the law of random variable distribution.

The following are the main characteristics of the operational activities of the divisions of the state fire service: the number of departures of divisions of the state fire service; the distance to the place of call of the state fire service unit; the time it takes for operational departments to arrive at the place of call; the number of departments on the main and special types of fire trucks involved in extinguishing a fire; the temporal characteristics of the development and extinguishment of a fire. All of these properties are random variables, and their distribution functions may provide them. [6].

The number of departures and departments participating in putting out a fire have a distribution that corresponds to the theoretical Poisson's law [6]. The distance to the site of call of the state fire service unit is apportioned in accordance with standard law.

The time required to extinguish all flames follows an exponential rule. The following principles govern the simulation modeling of operational activities in line with the aforementioned theoretical laws of the distribution of a random variable.

The duty dispatch service (city or district) gets signals about probable fires, accidents, and other occurrences at random intervals with a specific intensity, the divisions of which are involved in the elimination of which the divisions of the state fire service should participate. The dispatcher dispatches one or more operational departments based on the schedule of departures and the nature of the incoming call. Each call is also serviced for a random amount of time before the operational department returns to its deployment location and waits for the next call.

The exponential law-distributed distribution function of a random variable x:

$$F(x) = \begin{cases} 0 & npu \quad x < 0 \\ 1 - e^{-\lambda x} & npu \quad x \geq 0 \end{cases} \quad (3)$$

Distribution function of a random variable *x* distributed uniformly on a segment [*a*, *b*]:

$$F(x) = \begin{cases} 0 & при \quad x < a \\ \frac{x-a}{1-c} & при \quad a \le x \ge b \\ b & при \quad x > b \end{cases} \quad (4)$$

A discrete random variable *x* has a Poisson distribution if it takes the values 0, 1, 2, ..., *m* with probabilities:

$$P_m = \frac{\lambda^m e^{-\lambda}}{m!}. \quad (5)$$

The procedure of receiving calls to an industrial enterprise's or territorial unit's control room is uneven and unpredictable. The amount of calls received per unit of time is a discrete random variable that varies with time interval length [6]. The important temporal feature in this situation is the time of employment of fire departments. The employment time of a fire department is defined as the time between leaving the unit on calls and being assigned to a combat crew, or until they are ready for the next departure after returning to their deployment location. This trait is the result of numerous lengthy periods of time. [3].

The call service busy time (τ zan) is the sum of:

$$\boldsymbol{\tau}_{зан} = \boldsymbol{\tau}_{сооб.} + \boldsymbol{\tau}_{сле.д} + \boldsymbol{\tau}_{б.\,р.} + \boldsymbol{\tau}_{лок.} + \boldsymbol{\tau}_{лик.} + \boldsymbol{\tau}_{свер.} + \boldsymbol{\tau}_{возв.} + \boldsymbol{\tau}_{пост.б.р}. \quad \textbf{(6)}$$

Here: $\boldsymbol{\tau}_{сооб.}$ – this is the time taken for the dispatcher to receive a message about a fire and collect the personnel of the combat crews of the alert unit (assumed to be 1 minute);

$\boldsymbol{\tau}_{след.}$ – the time for units to go to the fire is determined:

$$\boldsymbol{\tau}_{след.} = L*60/V_{след.}, \quad \textbf{(7)}$$

here ***L*** – the path from the place of deployment of the fire department to the place of fire, km;

$V_{след.}$ – following speed is assumed to be from 30 to 45 km/h;

$\boldsymbol{\tau}_{б.р.}$ – Time required for combat deployment of fire departments to build hose lines, position a vehicle near a water supply, and prepare specific equipment, min. Accepted in compliance with fire drill training standards: 3 minutes during the summer, 6-8 minutes during the winter [6];

$\boldsymbol{\tau}_{лок.}$ – the time of fire localization, that is, from the time fire extinguishing chemicals are delivered to suppress the fire until the fire area's expansion stops and the condition is satisfied: $\mathbf{Q_{факт.} > Q_{тр.}}$, here $Q_{факт.}$ and $Q_{тр.}$ – respectively, the actual and estimated costs of fire extinguishing agents for fire extinguishing;

$\boldsymbol{\tau}_{лик}$.– fire extinguishing time - the time elapsed between the localization of the fire and the termination of combustion and all hostilities related with extinguishing the fire.;

$\boldsymbol{\tau}_{свер.}$ – the time taken by the unit gathering and packing fire-fighting equipment and weaponry.

Thus, the theoretical scientific study undertaken necessitates the development of specialist software capable of simulating various states of the situation in a fire and determining the dangerous aspects of its growth.

The evaluation system of features of the development of a fire at the facility and the outcomes of the operations of the state fire service units contains numerous indicators, which increases the dimension of the data; thus, appropriate software must be developed.

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