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RESEARCH AND JUSTIFICATION OF THE TIME FOR CONDUCTING OPERATIONAL ACTIONS BY FIRE AND RESCUE UNITS TO RESCUE PEOPLE IN A FIRE

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SUMMARY: The paper conducts research to determine and justify the total time of rescuing people in a fire in case of threat to their lives. It is established that the total time of rescuing people in a fire consists of the time before the report of the fire, the time of collection and departure of the unit, the time of departure and the time of operational deployment. Which in turn are determined depending on such indicators as the number of fire and rescue units and their location, their tactical capabilities and equipment of fire and rescue vehicles and fire equipment, population density, road coverage, terrain and operational and tactical characteristics of the area departure of the unit. Graphically shows the components of the total time of rescuing people in a fire, depending on these indicators. Also, a comparative analysis of the total time of rescuing people in a fire, taking into account the scheme number, period and place of use of the fire and rescue unit with the safe time of people in the room before the fatal concentration of carbon monoxide. The obtained results allow researchers to determine the total time of rescuing people in a fire with the appropriate adjustment of its components and the introduction of their relevant documentation. The paper also substantiates the choice of the scheme of operational deployment of the fire and rescue unit upon arrival at the scene of the fire.

Key words: *fire, carbon monoxide, rapid deployment, fire and rescue units*

INTRODUCTION

The main operational task of the personnel of fire and rescue units of the Central Command during firefighting is to rescue people in case of threat to their lives and extinguish fires *(Charter of action…, 2018)*. Execution of the operational task is provided by forces and devices *(Korytchenko et al., 2018a, Ostapov et al., 2019, Dubinin et al., 2018)*.

The process of fire development during the combustion of solid combustible materials is divided into phases of combustion, intensive combustion and extinction *(Pospelov et al., 2018, 2019)*. The duration of each period depends on the design features of the planning of the building or structure, the flammability of the materials in them *(Pospelov et al., 2018a, 2020)*. When organizing fire extinguishing, it is important to create conditions that allow the first unit to arrive on site of the fire and introduce extinguishing agents in the first period of the fire, when to localize and eliminate combustion using minimal forces and devices *(Steen-Hansen et al., 2020)*. The duration

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of burning solid combustible materials during this period varies from 3 to 30 minutes.

Fire statistics show that most fires in the living area, which occur inside the house with closed windows and doors, spread outside after 20-30 minutes, and when open - within a few minutes *(Analytical materials, 2020)*.

The time factor has always been given great importance in firefighting - not hours, but minutes, sometimes even seconds can solve the problem of saving lives in a fire *(Sund, Jaldel, 2018, Conduct research and…, 2007)*.

Thus, in the readiness of fire and rescue units to act on purpose was assessed, where the main indicators in conducting research are their professional and technical readiness and tactical capabilities *(Tiutiunyk et al., 2018, Wu, Wu, 2011)*. In the method of the analysis of indicators of operative reaction of fire and rescue divisions is offered thus the basic indicators are time of free development of fire, quantity of the operative vehicles which are involved in carrying out operative works, distance to a fire place, quantity extinguishing and protection *(Vlasov, Denisov, 2016)*. The authors *(Aldabbas et al., 2018, van den Berg et al., 2017)* proposed a method of choosing the optimal location of units in the village. It should be noted that when determining the time of rescue of people in the fire, some indicators were not taken into account.

The effectiveness of rescuing people in fires largely depends on the time before the report of the fire, the collection and departure of the unit, the direction of the fire and the rapid deployment, rapid deployment of fire and rescue units. This problem is especially acute for settlements where the state of fire safety is still insufficient. Given the importance of this problem, the Government has adopted a resolution *(Criteria for the formation…, 2013)*, the implementation of which should improve the situation, but there are a number of issues that need to be addressed. The standardized radius of service by one state fire and rescue unit on public roads should not exceed 3 km *(Criteria for the formation…, 2013)*, but in fact it is currently much larger in both cities and settlements. It is also necessary to take into account that if industrial enterprises are located in the exit zone of the unit, the service radius, depending on the category of production is up to 2 or 4 km *(Criteria for the formation…, 2013)*. Therefore, there is a problem related to exceeding the standard distance from the objects to the fire and rescue units. With this in mind, in accordance with the same Resolution *(Criteria for the formation…, 2013)* introduced standards for the arrival of state fire and rescue units to the place of call, which should not exceed: in the cities - 10 minutes; in settlements outside the city - 20 min *(Criteria for the formation…, 2013)*.

Therefore, the issue of rationing the time of rescuing people in a fire is more in line with the tasks of fire and rescue units during operational operations in settlements than the rationing of the service radius. This is due to a number of factors, such as population density, road coverage and terrain. At present, the methods of placing fire and rescue units do not allow to fully perform the tasks assigned to them, because instead of extinguishing fires, as a rule, the neighboring buildings are cooled and the fire is prevented from spreading. And rescuing people and extinguishing the fire at the time of arrival is no longer a priority due to the long time of free development of the fire *(Liu et al., 2020)*. Also, the rapid arrival of fire and rescue units, as mentioned above, is influenced by road coverage and terrain, which for settlements are not adapted for the passage of fire and rescue vehicles *(Liu et al., 2020a)*.

Given the above, in determining the total time of rescuing people in a fire the main role is played by such indicators as the number and location of fire and rescue units, their tactical capabilities equipped with fire and rescue vehicles and firefighting equipment, as well as professional training of firefighters *(Kiran, Corcoran, 2017, Liu et al., 2020b)*. Also, when determining the total time of rescuing people in a fire, it is necessary to take into account the safe time for people in a room in which the composition of the gaseous environment has deteriorated before the fatal concentration of carbon monoxide due to fire *(Dubinin et al., 2020)*.

Thus, substantiation and determination of the time of rescue of people on fire and its components is an urgent task in carrying out operational actions on rescue operations and fire extinguishing.

MATERIALS AND METHODS

To determine the time of rescuing people in a fire in the event of a threat to their lives depends on the timely arrival at the scene of fire and rescue units. Empirical and theoretical research methods were used to substantiate and determine the time of human rescue and its dependencies. That allowed to compare the requirements of regulations, to assess the dependence of the time of rescuing people and compare it with the safe time of people in the room before the lethal concentration of carbon monoxide. Using the least squares method, the data of the operational deployment time are processed. With the help of general scientific research methods the analysis of components of time of rescue of people on fire by fire and rescue divisions is carried out, and also the received results of calculation are presented in the form of graphs.

RESULTS AND DISCUSSION

During the rescue operations of fire and rescue units, it is necessary to arrive at the scene of the fire in the shortest possible time and to involve the necessary forces and devices to rescue people in danger *(Charter of action…, 2018, Ragimov et al., 2018)*. Based on this, it is necessary to justify the time of rescuing people depending on the training of fire and rescue personnel, equipped with a fire and rescue vehicle and firefighting equipment, as well as the time of operational activities directly at the scene of the fire.

The total time of rescuing people in a fire in the event of a threat to their lives, taking into account *(Handbook of Chief…, 2016)* looks like:

$$t_{res.} = t_{t.r.} + t_{cd.} + t_{trav.} + t_{o.d.}, \quad [1]$$

where $t_{t.r.}$ – time to report the fire, min.; $t_{cd.}$ – time of collection and departure of the unit, min.; $t_{trav.}$ - travel time to the place of fire, min.; $t_{o.d.}$ - time of operative deployment, min.

Consider each component of expression [1], so the time to report a fire, which consists of detecting and notifying the fire and rescue unit of the fire, is determined on the basis of statistics on firefighting in practical calculations takes about 8-12 minutes *(Handbook of Chief…, 2016)*. But it should be noted that during this period the level of telephony has improved significantly, especially in modern conditions, with the beginning of widespread use of mobile communications and given its further development, as well as analyzing statistics on fires, this figure for further calculations 5 min

The time of collection and departure depends on the operational readiness of fire and rescue units and is accepted according to established standards *(Standards for the implemention…, 2015)*. But for a guard consisting of two or more compartments, the maximum time of collection and departure on the "Alarm" signal is 45 seconds, but taking into account the departure of the fire and rescue vehicle outside the unit, for further calculations we take 1 minute.

The travel time to the place of fire by fire and rescue vehicles depends on the distance, travel conditions and is determined by the formula *(Handbook of Chief…, 2016)*:

$$t_{trav.} = \frac{L \cdot 60}{V_{av}}, \quad [2]$$

where L is the distance from the unit to the place of fire, km; V_{av} - the average speed of fire and rescue vehicles.

In connection with the adoption *(Criteria for the formation…, 2013)*, which sets the time of arrival of state fire and rescue units to the place of call, which should not exceed: in the cities - 10 minutes; in settlements outside the city - 20 minutes. Taking into account meteorological conditions, seasonal features and condition of roads, the arrival standards may be exceeded, but not more than for 5 minutes. For further calculations we accept for the city - 10 minutes, for the settlement - 20 minutes.

The time of operational deployment is taken in accordance with the standards established in *(Standards for the implemention…, 2015)* and depends on the scheme of operational deployment of forces and devices, the situation on the fire and operational and tactical characteristics of the area (object). When determining the time of operational deployment, it is necessary to take into account the supply of fire extinguishing agent to extinguish

the fire, as well as to accept different operating conditions (summer and winter). With this in mind, the most practical schemes of use during rescue operations are taken, which are shown in Fig. 1-5 Thus, according to schemes 1–5 in the summer period and according to schemes 1–2 in the winter period, we supply fire extinguishing agent, and in the winter period according to schemes 3–5 without supplying fire extinguishing agent. In addition, it is necessary to take into account the time for the operational inspection of the personnel of the unit at the entrance of the gas smoke protection service element in a smoky or gassy environment. The operative check is carried out by the gas-smoke protector before each inclusion in devices of individual protection of respiratory and sight organs and should last no more than 1 min. *(Attitude for the organization…, 2011)*. Given the requirements *(Standards for the implemention…, 2015, Attitude for the organization…, 2011)* and fire statistics *(Analytical materials, 2020)*, we adopt the most common schemes for the rapid deployment of forces and devices.

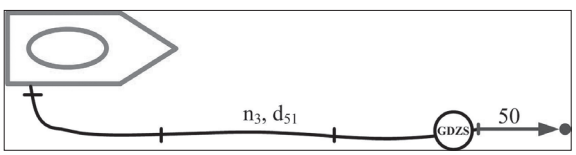

Figure 1. The scheme of supply of one fire barrel "B" through a working line on three firehoses d 51 mm from the fire tanker

Slika 1. Shema opskrbe jedne vatrogasne cijevi "B" kroz radnu liniju na tri vatrogasne cijevi d 51 mm od vatrogasne cisterne

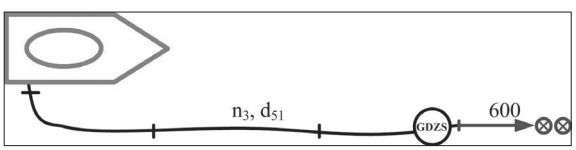

Figure 2. The scheme of giving of a "GPS-600" fire barrel through a working line on three firehoses d 51 mm from the fire tanker

Slika 2. Shema davanja protupožarne cijevi "GPS-600" kroz radnu liniju na tri vatrogasne cijevi d 51 mm od vatrogasne cisterne

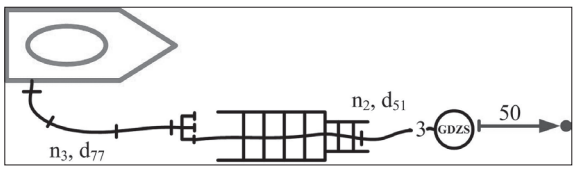

Figure 3. The scheme of supply of a fire barrel "B" from the fire tanker on a sliding ladder in a window of the 3rd floor of a training tower with laying of the main line on three firehoses d 77 mm and a working line on two firehoses d 51 mm

Slika 3. Shema opskrbe protupožarne cijevi "B" iz vatrogasne cisterne na kliznim ljestvama u prozoru 3. kata vježbenog tornja s polaganjem glavne linije na tri vatrogasne cijevi d 77 mm i radnom linijom na dvije vatrogasne cijevi d 51 mm

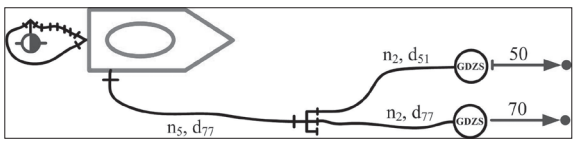

Figure 4. The scheme of supply of one fire barrel "A" and one fire barrel "B" with laying of the main line on five firehoses d 77 mm and two working lines (on two firehoses d 51 mm and two firehoses d 77 mm) with installation of the fire tanker on a fire hydrant

Slika 4. Shema opskrbe jedne vatrogasne cijevi "A" i jedne vatrogasne cijevi "B" s polaganjem glavnog voda na pet vatrogasnih cijevi d 77 mm i dvije radne linije (na dvije vatrogasne cijevi d 51 mm i dvije vatrogasne cijevi d 77 mm) s ugradnjom vatrogasne cisterne na požarni hidrant

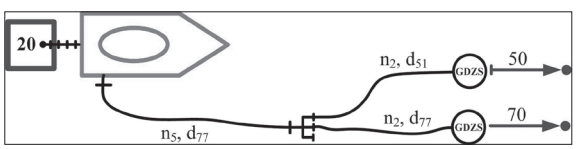

Figure 5. The scheme of supply of one fire barrel "A" and one fire barrel "B" with laying of the main line on five firehoses d 77 mm and two working lines (on two firehoses d 51 mm and two firehoses d 77 mm) with installation of the fire truck

Slika 5. Shema opskrbe jedne vatrogasne cijevi "A" i jedne vatrogasne cijevi "B" s polaganjem glavnog voda na pet vatrogasnih cijevi d 77 mm i dvije radne linije (na dvije vatrogasne cijevi d 51 mm i dvije vatrogasne cijevi d 77 mm) uz ugradnju vatrogasnog vozila

The obtained values of the components of expression [1] are entered in table 1 for a preliminary calculation to determine the total time of rescue operations. The time of operational deployment of fire and rescue units on the fire will be processed using the method of least squares and the obtained root mean square (rms) value will be entered in Table 1.

Thus, Table 1 shows the generalized values of the time to report the fire, which is 5 minutes, the time of collection and departure of the unit - 1 minute, the time of travel to the place of fire - to the city - 5 minutes, and for the settlement respectively 10 minutes, as well as the root mean square value of the time of operational deployment, depending on the number of the scheme, period and place of use. Using the data in table 1, we analyze them by plotting the graphs presented in Fig. 6-9.

Table 1. The initial data for the calculation the total time of rescuing people in a fire

Tablica 1. Početni podaci za izračun ukupnog vremena spašavanja ljudi u požaru

<table>
<tr><th rowspan="3">$t_{t.r}$ min.</th><th rowspan="3">$t_{.cd}$, min</th><th colspan="2">$t_{trav.}$, min.</th><th colspan="10">$t_{o.d.}$ min.</th></tr>
<tr><th rowspan="2">city</th><th rowspan="2">settlement</th><th colspan="10">scheme number (#)</th></tr>
<tr><th colspan="2">1</th><th colspan="2">2</th><th colspan="2">3</th><th colspan="2">4</th><th colspan="2">5</th></tr>
<tr><td rowspan="8">5</td><td rowspan="8">1</td><td rowspan="8">10</td><td rowspan="8">20</td><td colspan="10">summer time</td></tr>
<tr><td>1,38</td><td rowspan="3">$1,42\pm2,385_{0,9}$</td><td>1,48</td><td rowspan="3">$1,53\pm2,563_{0,9}$</td><td>1,98</td><td rowspan="3">$2,08\pm3,487_{0,9}$</td><td>3,25</td><td rowspan="3">$3,33\pm5,583_{0,9}$</td><td>3,32</td><td rowspan="3">$3,40\pm5,695_{0,9}$</td></tr>
<tr><td>1,42</td><td>1,53</td><td>2,08</td><td>3,33</td><td>3,40</td></tr>
<tr><td>1,47</td><td>1,58</td><td>2,18</td><td>3,42</td><td>3,48</td></tr>
<tr><td colspan="10">winter time</td></tr>
<tr><td>1,63</td><td rowspan="3">$1,67\pm 2,803_{0,9}$</td><td>1,73</td><td rowspan="3">$1,78\pm 2,982_{0,9}$</td><td>2,15</td><td rowspan="3">$2,25\pm 3,771_{0,9}$</td><td>3,00</td><td rowspan="3">$3,08\pm 5,165_{0,9}$</td><td>3,30</td><td rowspan="3">$3,38\pm 5,667_{0,9}$</td></tr>
<tr><td>1,67</td><td>1,78</td><td>2,25</td><td>3,08</td><td>3,38</td></tr>
<tr><td>1,72</td><td>1,83</td><td>2,35</td><td>3,18</td><td>3,47</td></tr>
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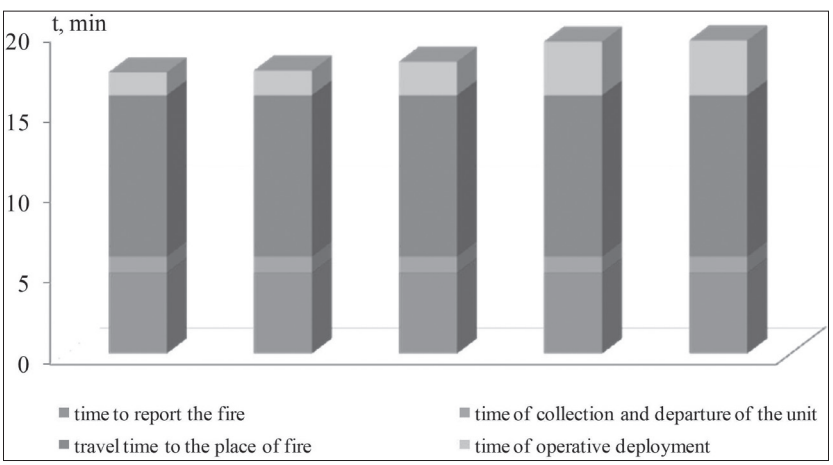

Figure 6. The total time of rescuing people during summer time – city
Slika 6. Ukupno vrijeme spašavanja ljudi tijekom ljeta - grad

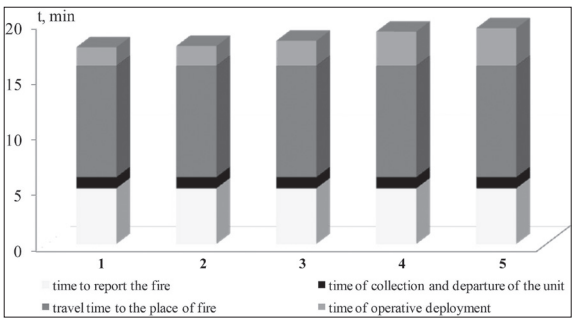

Figure 7. Winter time – city
Slika 7. Zimsko vrijeme - grad

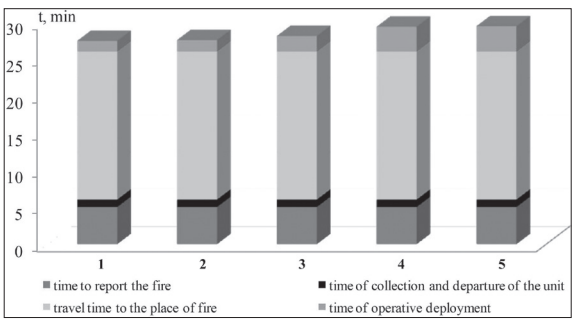

Figure 8. Summer time – settlement
Slika 8. Ljetno vrijeme - naselje

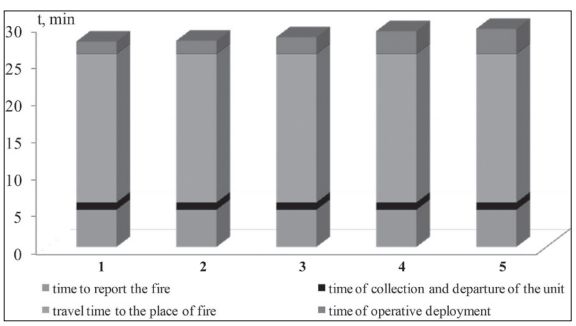

Figure 9. Winter time – settlement
Slika 9. Zimsko vrijeme – naselje

Using the data from table 1 and using expression (1), we calculate the total time of rescuing people in a fire. The obtained calculated values, taking into account the number of the scheme and the period of use, are entered in Table 2.

Table 2. Calculation of the total time of rescue of people on fire

Tablica 2. Izračun ukupnog vremena spašavanja ljudi u požaru

Scheme number	$t_{res.}$, min.			
	summer time		winter time	
	city	settlement	city	settlement
1	17.42	27.42	17.67	27.67
2	17.53	27.53	17.78	27.78
3	18.08	28.08	18.25	28.25
4	19.33	29.33	19.08	29.08
5	19.4	29.4	19.38	29.38

To determine the tactical capabilities of fire and rescue units, we will compare the calculated data of the total time of rescuing people in a fire with the safe time of people in the room before the lethal concentration of carbon monoxide.

The safe time of people in a room in which the composition of the gaseous environment has deteriorated due to fire, depending on the concentration of carbon monoxide will be taken from work *(Dubinin et al., 2020)*. The danger of carbon monoxide for a person in a fire *(Criteria for the formation…, 2013, Pospelov et al., 2018)* and in the operation of internal combustion engines of vehicles *(Kasimov et al., 2018, Korytchenko et al., 2018)* is to establish a lethal concentration of carbon monoxide in the air, which is 0.3% or (0.003 kg / m³), which in a matter of minutes will lead to the death of a person who is in the room. Poisoning by this gas occurs as a result of a critical lack of oxygen in the body. From *(Dubinin et al., 2020)* were taken the critical value of safe time, during which the lethal concentration of carbon monoxide (CO) in the gaseous medium in the building is 17 minutes.

Using the data in table 2, we construct graphs taking into account the scheme number, period and place of use of the fire and rescue unit and compare with the safe time of people in the room before the lethal concentration of carbon monoxide (CO), presented in Fig. 10–11.

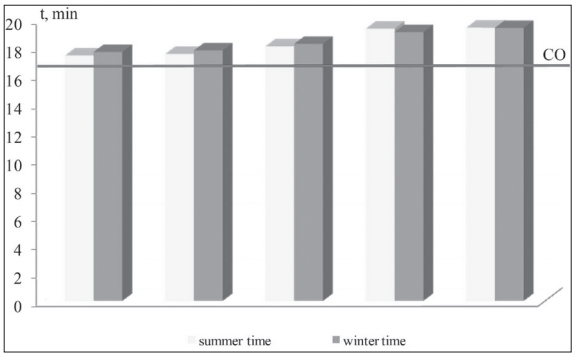

Figure 10. Dependence of rescue time on safe time (SA) for the city

Slika 10. Ovisnost vremena spašavanja o sigurnom vremenu (SA) za grad

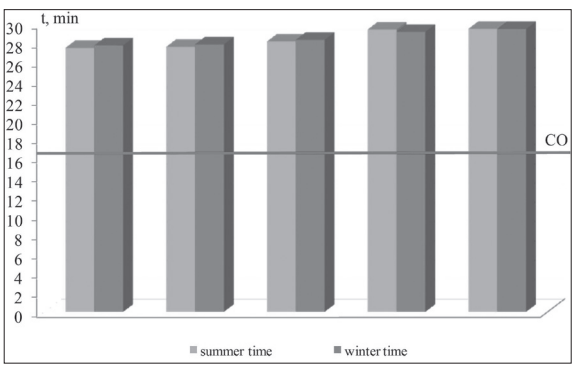

Figure 11. Dependence of rescue time on safe time (CO) for the settlement

Slika 11. Ovisnost vremena spašavanja o sigurnom vremenu (CO) za naselje

The total time of arrival of the first fire and rescue unit to the scene of the fire to provide assistance may, in the case of revision, lead to a change in the location of units, the boundaries of service areas, a reasonable increase in the number of fire and rescue units.

Population density and the number of inhabitants in individual cities and settlements in a given service area will affect the number of fire and rescue units and the location of the unit relative to the area with the highest density.

The required number of fire and rescue vehicles depends on the number of fires, their distribution by frequency of use and time of service of calls.

The complex operational and tactical characteristics of cities and settlements determine the special requirements for the organization of firefighting in residential and industrial areas and the involvement of the necessary forces and devices of civil protection.

Analyzing the above and the obtained comparative results, shown in Fig. 6-9 it can be noted that the time before the fire notification, the time of collection and departure of the unit, the time of travel to the scene of the fire will primarily depend on the number of fire and rescue units depending on the characteristics of the service area and timely notification of the unit. And if we consider the time of operational deployment, it will primarily depend on the scheme of operational deployment. In accordance with the requirements of *(Charter of action…, 2018)* the rapid deployment of forces and devices after the arrival of the fire and rescue unit is carried out simultaneously with reconnaissance, taking into account occupational safety requirements and should not delay rescue and evacuation, and in the presence of signs of burning reconnaissance is carried out. Fire and rescue units that first arrived at the scene of the fire take measures to rescue people and contain the spread of fire until the arrival of additional forces and devices by providing a first aid barrel. The fire truck that arrived first at the scene of the call shall be installed at a safe distance as close to the scene of the fire as possible from the windward side and from it the first fire barrel shall be fed in the decisive direction or to provide reconnaissance. Subsequent fire trucks are installed at the nearest sources of fire water supply, main lines are laid and water is supplied from them to the main tank *(Charter of actions…, 2018)*. With this in mind, it is advisable to use schemes № 1-2 operational deployment when the fire arrived guard in one department, ie at the initial stage, and if you want to submit the fire barrel to the second or third floor then it is necessary to conduct operational deployment according to scheme № 3. Schemes 4-5 it is advisable to use a guard consisting of two or more divisions upon arrival at the fire, when the fire has developed significantly or rescuing people should be carried out in several directions with simultaneous firefighting. Therefore, the time of operational deployment will be determined in advance in accordance with the scheme of use, as well as the professional training of personnel of the fire and rescue unit.

Analyzing the comparative results of the total time of rescuing people in a fire with the safe time of people in the room before the lethal concentration of carbon monoxide, which are presented in Fig. 10-11. It can be noted that comparing this dependence for the city and the settlement, the percentage of rescuing people by fire and rescue units in cities will be much higher than in settlements, provided that the scheme of operational deployment № 1-2. Analyzing fig. 9., while the safe time of people in the room before the lethal concentration of carbon monoxide is 17 minutes, and the total rescue of people under the scheme № 1 is 17.42 minutes in summer and 17.67 minutes in winter. , respectively according to the scheme № 2 in summer - 17.53 minutes, and winter - 17.78 minutes. This devices that fire and rescue units stationed and the exit area in the cities will have time to rescue people from the fire. And conducting an analysis of Figs. 10. The minimum time for rescue work is approximately 27 minutes. while the safe time of people in the room before the lethal concentration of carbon monoxide is 17 minutes this devices that it is almost impossible to save a person.

According to statistics, in 2018 there were 31,501 fires in rural areas, which is more than 40% of all fires that occurred in Ukraine, killing 1,070 people, causing significant damage to households *(Methodical materials, 2020)*. There is an urgent need to organize firefighting in rural areas, where there are a large number of settlements, the time of arrival of the first unit in which exceeds the maximum allowable values (20 minutes). Over the last ten years, the average time of arrival of the first unit to the place of call in Ukraine has fluctuated - from 13.0 minutes. up to 14.6 minutes, in cities and towns - from 9.4 minutes. up to 9.9 minutes, in rural areas - from 19.2 minutes. up to 21.8 minutes, ie the difference between rural areas and cities (urban-type settlements) is more than 2 times. At the same time, for 700-800 calls a year, the arrival time of the unit is 70–73 minutes *(Methodical materials, 2020)*. One of the ways to solve this issue is the formation of fire and rescue units to provide local and voluntary fire protection *(Methodical materials, 2020)*. Involvement of local and voluntary fire protection to extinguish fires and rescue people in cities and towns will greatly simplify the structure to reduce the time of fire rescue operations. Further development and improvement of their activities requires justification of their level of efficiency and resources sufficient to achieve this level. Such justifications can be obtained only in the presence of objective criteria that characterize various aspects of local and voluntary fire protection and take into account the specifics of individual regions. To obtain objective criteria, it is necessary to know the relationship between the size of the consequences of possible fires and the cost of fire protection. This requires, in turn, the study of the structure of the consequences of fires, quantification of their size, including the size of direct and incidental material damage, taking into account the economic links between the objects of protection in terms of their specialization and cooperation. This also includes the problem of qualitative and quantitative assessment of fire hazard of facilities and administrative-territorial units, which is due to the possible consequences of fires. In the framework of these studies it is necessary to take into account, on the one hand, the requirement of development and strengthening of material and technical base, which provides local and voluntary fire protection to increase the level of fire protection of cities and towns. On the other hand, it is necessary to improve the forms and methods of organizational and mass and operational work aimed at preventing and extinguishing fires. These conditions for improving the activities of local and voluntary fire protection should be considered in conjunction as a whole in a comprehensive solution to the issues of improving the level of fire protection of cities and towns.

CONCLUSIONS

A comparative assessment of the components of the total time of rescuing people in a fire, namely the time to report the fire, the time of collection and departure of the unit, the time of travel to the scene of the fire and the time of operational deployment. It is established that the effectiveness of rescuing people in fires largely depends on the time of arrival and the time of operational deployment of fire and rescue units. Thus, the time of operational deployment will depend on the scheme of use and professional training of personnel of the fire and rescue unit, and the time of the unit to the place of fire will depend on their

number and location, condition of fire vehicles and fire fighting equipment and road coverage.

A comparative analysis of the total time of rescuing people in a fire with the safe time of people in the room before the fatal concentration of carbon monoxide. It is established that for rescue of people for the city it is necessary to use schemes of operative deployment № 1–3 thus rescue time will make about 17 minutes, and for the settlement at the expense of considerable time of direction of division on fire rescue time makes about 27 minutes that influences first of all, the course of operational operations to rescue people.

The received substantiation and results of researches allow to make certain changes in construction and definition of quantity of local and voluntary fire protection in the cities and settlements for the purpose of increase of efficiency of carrying out by fire and rescue divisions of operative actions on rescue of people and fire extinguishing.

LITERATURE

Aldabbas, M., Venteicher, F., Gerber, L., Widmer, M.: Finding the Adequate Location Scenario After the Merger of Fire Brigades Thanks to Multiple Criteria Decision Analysis Methods, *Foundations of Computing and Decision Sciences*, 43, 2018, 2, 69–88, DOI: 10.1515/fcds-2018-0006.

Analytical materials. Accessible at: URL: https://idundcz.dsns.gov.ua/ua/Analitichni-materiali.html, Accessed: 2021-01-19.

Attitude for the organization of the gas and smoke protection service in the units of the Operational and Rescue Service of the Civil Defense of the Ministry for Emergencies of Ukraine, Order of the Ministry of Emergencies of Ukraine № 1342 dated 16.12.2011. Accessible at: URL: https://zakon.rada.gov.ua/rada/show/v1342735-11#Text, Accessed: 2021-01-19.

Charter of actions of management bodies and divisions of the Operational and Rescue Service of Civil Protection during firefighting, Order of the Ministry of Internal Affairs of Ukraine № 340 dated 26.04.2018, Accessible at: URL: https://zakon.rada.gov.ua/rada/show/v1342735-11#Text, Accessed: 2021-01-19.

Conduct research and develop software to determine the coverage of fire protection units in rural settlements: Report on research, Ukrainian fire safety research institute, Ministry of Emergencies of Ukraine, №106U005414, 2007.

Criteria for the formation of state fire and rescue units (parts) of the Operational and Rescue Service of Civil Defense in administrative-territorial units and the list of business entities where such units (parts) are formed, Resolution of the Cabinet of Ministers № 874 of November 27, 2013, Accessible at: URL: https://zakon.rada.gov.ua/laws/show/874-2013-%D0%BF#Text, Accessed: 2021-01-19

Dubinin, D., Korytchenko, K., Lisnyak, A., Hrytsyna, I., Trigub, V.: Improving the installation for fire extinguishing with finelydispersed water, *Eastern-European Journal of Enterprise Technologies*, 92, 2018, 2/10, 38–43, DOI: 10.15587/1729-4061.2018.127865.

Dubinin, D., Avetisyan, V., Ostapov, K., Shevchenko, S., Hovalenkov, S., Beliuchenko, D., Maksymov, A., Cherkashyn, O.: Investigation of the effect of carbon monoxide on people in case of fire in a building, *Sigurnost*, 62, 2020, 4, 347–357, DOI: 10.31306/s.62.4.2.

Handbook of Chief of firefighting brigade during extinguishing fire/Edited by V. S. Kropyvnytsky, Kiev, 2016, 320.

Kasimov, A., Korytchenko, K., Dubinin, D., Lisnyak, A., Slepuzhnikov, E., Khmyrov, I.: Numerical study of the process of compressing a turbulized two-temperature air charge in the diesel engine, *Eastern-European Journal of Enterprise Technologies*, 96, 2018, 6/5, 49–53, DOI: 10.15587/1729-4061.2018.150376.

Kiran, K. C., Corcoran, J.: Modelling residential fire incident response times: A spatial analytic approach, *Applied Geography*, 84, 2017, 64–74, DOI: 10.1016/j.apgeog.2017.03.004.

Korytchenko, K. V., Ozerov, A.N., Vinnikov, D. V., Skob, Yu A., Dubinin, D. P., Meleshchenko, R. G.: Numerical simulation of influence of the non-equilibrium excitation of molecules on direct detonation initiation by spark discharge, *Problems of Atomic Science and Technology*, 2018, 4/116, 194–199.

Korytchenko, K., Sakun, O., Dubinin, D., Khilko, Y., Slepuzhnikov, E., Nikorchuk, A., Tsebriuk, I.: Experimental investigation of the fire-extinguishing system with a gasdetonation charge for fluid acceleration, *Eastern-European Journal of Enterprise Technologies*, 93, 2018a, 3/5, 47–54, DOI: 10.15587/1729-4061.2018.134193

Liu, D., Xu, Z., Wang, Z., Zhou, Y., Fan, C.: Estimation of effective coverage rate of fire station services based on real-time travel times, *Fire Safety Journal*, 120, 2021, 103021, DOI: 10.1016/j.firesaf.2020.103021.

Liu, D., Xu, Z., Wang, Z., Fan, C.: Regional evaluation of fire apparatus requirements for petrol stations based on travel times, *Process Safety and Environmental Protection*, 135, 2020a, 350–363, DOI: 10.1016/j.psep.2020.01.012.

Liu, D., Xu, Z., Yan, L., Fan, C.: Dynamic estimation system for fire station service areas based on travel time data, *Fire Safety Journal*, 118, 2020b, 103238, DOI: 10.1016/j.firesaf.2020.103238.

Methodical materials, Accessible at: URL: https://www.dsns.gov.ua/ua/Metodichni-materiali.html, Accessed: 2021-01-19

Ostapov, K., Kirichenko, I., Senchykhin, Y., Syrovyi, V., Vorontsova, D., Belikov, A., Karasev, A., Klymenko, H., Rybalka, E.: Improvement of the installation with an extended barrel of cranked type used for fire extinguishing by gel-forming compositions, *Eastern-European Journal of Enterprise Technologies*, 100, 2019, 4/10, 30-36, DOI: 10.15587/1729-4061.2019.174592.

Pospelov, B., Andronov, V., Rybka, E., Popov, V., Semkiv, O.: Development of the method of frequencytemporal representation of fluctuations of gas environment parameters at fire, Eastern-*European Journal of Enterprise Technologies*, 92, 2018, 2/10, 44–49, DOI: 10.15587/1729-4061.2018.125926.

Pospelov, B., Krainiukov, O., Savchenko, A., Harbuz, S., Cherkashyn, O., Shcherbak, S., Rolin, I., Temnikov, V.: Development of the method operative calculation the recurrent diagrams for non-regular measurements, *Eastern-European Journal of Enterprise Technologies*, 101, 2019, 5/4, 26–33, DOI: 10.15587/1729-4061.2019.181516.

Pospelov, B., Andronov, V., Rybka, E., Meleshchenko, R., Gornostal, S.: Analysis of correlation dimensionality of the state of a gas medium at early ignition of materials, *Eastern-European Journal of Enterprise Technologies*, 95, 2018a, 5/10, 25–30, DOI: 10.15587/1729-4061.2018.142995.

Pospelov, B., Rybka, E., Meleshchenko, R., Gornostal, S., Shcherbak, S.: Results of experimental research into correlations between hazardous factors of ignition of materials in premises, *Eastern-European Journal of Enterprise Technologies*, 90, 2017, 6/10, 50–56, DOI: 10.15587/1729-4061.2017.117789.

Pospelov, B., Danchenko, Y., Dadashov, I. F., Skliarov, S., Gornostal, S., Cherkashyn, O.: Analysis of detection of ecological hazard based on computing the measures of current recurrence of ecosystem states, *Eastern-European Journal of Enterprise Technologies*, 96, 2018b, 6/10, 6–13, DOI: 10.15587/1729-4061.2018.147508.

Pospelov, B., Andronov, V., Rybka, E., Popov, V., Romin, A.: Experimental study of the fluctuations of gas medium parameters as early signs of fire, *Eastern-European Journal of Enterprise Technologies*, 91, 2018c, 1/10, 50–55, DOI: 10.15587/1729-4061.2018.122419.

Ragimov, S., Sobyna, V., Vambol, V., Vambol, A., Feshchenko, A., Zakora, A., Strejekurov, E., Shalomov, V.: Physical modelling of changes in the energy impact on a worker taking into account high-temperature radiation, *Journal of Achievements in Materials and Manufacturing Engineering*, 91, 2018, 1, 27–33. DOI: 10.5604/01.3001.0012.9654.

Steen-Hansen, A., Storesun, K., Sessengb, C.: Learning from fire investigations and research – A Norwegian perspective on moving from a reactive to a proactive fire safety management, *Fire Safety Journal*, 3, 2020, 103047, DOI: 10.1016/j.firesaf.2020.103047.

Sund, B., Jaldell, H.: Security officers responding to residential fire alarms: Estimating the effect on survival and property damage, *Fire Safety Journal*, 97, 2018, 1-11, DOI: 10.1016/j.firesaf.2018.01.008.

Tiutiunyk, V. V., Ivanets, H. V., Tolkunov, I. A., Stetsyuk, E. I.: System approach for readi-

ness assessment units of civil defense to actions at emergency situations, Visnyk Natsionalnoho Hirnychoho Universytetu, 1, 2018, 99–105, DOI: 10.29202/nvngu/2018-1/7.

Wu, X., Wu, L.: Evaluation of the Fire Emergency Rescue Capability in Urban Community, *Procedia Engineering*, 11, 2011, 536–540, DOI: 10.1016/j.proeng.2011.04.693.

van den Berg, P. L., Guido, A., Legemaate, G., van der Mei, R. D.: Increasing the Responsiveness of Firefighter Services by Relocating Base Stations in Amsterdam, *INFORMS Journal on Applied Analytics*, 47, 2017, 352–361, DOI: 10.1287/inte.2017.0897.

Vlasov, K. S., Denisov, A. N.: Methods for analyzing indicators of operational response of fire and rescue units, *Technosphere safety technologies*, 67, 2016, 3, 207–213.

Standards for the implementation of training exercises to prepare members of the rank and file and senior staff of the Civil Defense Service and employees of the Rescue Service of the Civil Defense of the SES of Ukraine to perform the tasks assigned to them. Order of the Ministry of Internal Affairs of Ukraine № 1470 dated 20.11.2015. Accessible at: URL: https://zakon.rada.gov.ua/laws/show/z1528-15#Text, Accessed: 2021-01-19

ISTRAŽIVANJE I OPRAVDANJE VREMENA IZVOĐENJA OPERATIVNIH AKCIJA VATROGASNO-SPASILAČKIH POSTROJBI ZA SPAŠAVANJE LJUDI U POŽARU

SAŽETAK: U radu se prikazuje istraživanje kako bi se utvrdilo i opravdalo ukupno vrijeme spašavanja ljudi u požaru u slučaju prijetnje njihovim životima. Utvrđuje se da se ukupno vrijeme spašavanja ljudi u požaru sastoji od vremena prije dojave o požaru, vremena prikupljanja i odlaska postrojbe, vremena polaska i vremena operativnog raspoređivanja. Navedena se, pak, određuju ovisno o pokazateljima kao što su broj vatrogasno-spasilačkih postrojbi i njihov položaj, njihove taktičke sposobnosti i opremljenost vatrogasno-spasilačkih vozila i vatrogasne opreme, gustoća naseljenosti, pokrivenost cesta, terena i operativno-taktičke karakteristike područja odlaska postrojbe. Grafički se prikazuju komponente ukupnog vremena spašavanja ljudi u požaru, ovisno o ovim pokazateljima, također, i usporedna analiza ukupnog vremena spašavanja ljudi u požaru, uzimajući u obzir broj sheme, razdoblje i mjesto korištenja vatrogasno-spasilačke postrojbe sa sigurnim vremenom ljudi u sobi prije kobne koncentracije ugljičnog monoksida. Dobiveni rezultati omogućuju istraživačima da utvrde ukupno vrijeme spašavanja ljudi u požaru uz odgovarajuće podešavanje njegovih komponenata i uvođenjem njihove relevantne dokumentacije. U radu se također obrazlaže izbor sheme operativnog raspoređivanja vatrogasno-spasilačke postrojbe po dolasku na mjesto požara.

Ključne riječi: *požar, ugljični monoksid, brzo raspoređivanje, vatrogasno-spasilačke postrojbe*

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