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MINIMIZATION OF INTEGRAL RISK OF EMERGENCY ON THE EXAMPLE OF BLYZNYUKIVSKYI DISTRICT OF KHARKIV REGION

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The paper shows the inverse relationship between the coverage ratio of the region and the time of arrival to an emergency (dangerous event). the minimization of the integral risk of emergencies (dangerous events) was realized by increasing the number of fire depots on the example of Blyzniukivskyi district of Kharkiv region. Departure areas are shown on a real map in Google Maps.

The selection of an additional fire department to reduce the integral risk reduction includes the following restrictions: the minimum area of intersection of the areas of operation of the PDP in a given area; the affiliation of the areas of operation of the PDP; the minimum area of intersection of the areas of operation of the PDP with the areas of prohibition; the affiliation of the ATS and PNO of the area of intersection of the areas of operation of the PRP, providing response to the accident (fire) and the ATS or PNO in accordance with the call number; the time of arrival of the PRP to the most remote point of the departure area, should not exceed the specified; placement of PRP is carried out taking into account the limited resources.

Departure areas of fire and rescue units are convex polygons, the vertices of which depend on the road network. As a result of the increase from one fire station to four, the response time to the fire will be reduced by 51%, and the corresponding emergency risk will be reduced by 72%. During the increase in the number of fire departments, the arrival time of operational and rescue teams will decrease, which directly affects the reduction of the integrated fire risk. That is why, if funding is available, the number of fire departments can be increased.

Keywords: integral risk of emergency, coverage ratio, time of arrival, coverage area, rescue unit, fire station.

Statement of problem. In connection with the reform of the State Service of Ukraine for Emergencies and in accordance with the Strategy of its reform [1], one of the ways to solve the identified problems of the service is to determine the required number of fire and rescue units of local and voluntary fire protection in the united territorial communities and providing methodological assistance to local governments in establishing new and reforming existing rescue units (RUs). At the same time, the Strategy envisages the introduction of a man-made and fire safety management system based on a risk-oriented approach. Therefore, the urgent task is to identify parameters that affect the magnitude of integral risk, construction of models and methods of risk management, forecasting the level of risk for further development of sound recommendations for the deployment of new RUs taking into account reduction the level of integral risk of emergency for research area.

Recent research and publication analysis. In [2] the general function for definition and management of risk of technogenic danger is given, but the given model is calculated for risk at the enterprise and does not consider integral risk as a whole. In the United States, the assessment and management of fire risk is the agency FEMA, and the results of its activities are given in [3, 4]. However, these works do not contain information about the dependence of the magnitude of fire risk on the time of the RDP to the place of emergency. A similar conclusion can be made during the analysis of risk assessment methods in different countries of the world, given in the Global Concept of Fire Safety [5-7].

Setting article objectives. The purpose of the article is to minimize the risk of emergencies (dangerous events) on the example of Blyznyukivskyi district of Kharkiv region by increasing the number of fire stations.

Main part. In our previous work [8] as a result of the correlation-regression analysis it was found that the specified integral risk of an emergency (dangerous event) depends on such factors as N_{events} – the number of emergencies (dangerous events) recorded in the region; M_{vctims} – the number of deaths due to emergencies (dangerous events) in the region; τ_{arrive} – average time of arrival of RUs to the place of occurrence of an emergency situation (dangerous event); τ_{loc} – average time of localization of emergencies (dangerous events); τ_{liq} – average time of liquidation of emergencies (dangerous events). The main parameter that RUs should focus on is the standard time of arrival of units to the scene of an emergency. The normative time of arrival of RUs to the place of call [9–11] should not exceed: on the territory of cities – 10 minutes; in settlements outside the city – 20 minutes.

In [12] it was found that the time of arrival of RUs to the place of emergency (dangerous event) depends on the coverage of the area by service areas of RUs k_{cover}, which is determined by the following formula:

$$k_{\mathrm{cov}\,er} = \frac{S\left(\bigcup_{q=1}^{N_q} P_q\right)}{S(S_0)} \quad , \tag{1}$$

where N_q – the number of existing RUs; P_q – area of departure q-th unit; S_0 –

given territory; $s(.)$– area calculation function.

For the Kharkiv region, the following relationship was established [12] between the time of arrival to the place of call and the coverage ratio:

$$\bar{\tau}_{arrive} = -20{,}799 k_{cover} + 35{,}46. \quad (2)$$

From expression (2) it follows that with full coverage of RUs of the Kharkiv region service areas, the coverage factor is equal to one, the average time of arrival to the place of an emergency (dangerous event) will not exceed 15 minutes. This value is satisfactory, because outside the city the value of the time of the units should not exceed 20 minutes.

As an example, the coverage ratio for Blyznyukivskyi district of Kharkiv region was determined. The coverage area of the service area is equal to the area of the district 1380 km^2. The service area of the unit is equal to the sum of the service areas of all parts, taking into account their intersection. The service area of one unit will be the area of the circle with the corresponding service radius. Given the coverage of roads in rural areas, it was assumed that the speed of the bottom of the RU will be about 30 km/hour (v_{arrive}), and the time of arrival should not exceed 20 min, therefore, the service radius of one unit will be:

$$R_{service} = v_{arrive} \cdot \tau_{arrive} = 30 \cdot \frac{1}{3} = 10 \text{ km}. \quad (3)$$

Calculate the area of service by one unit:

$$S_{service} = \pi \cdot R^2_{service} = 3{,}14 \cdot 10^2 = 314 \text{ km}^2. \quad (4)$$

Having the value of the required areas, you can determine the coverage ratio of one unit in the Blyznyukivskyi district:

$$k_{cover} = \frac{314}{1380} = 0{,}2275. \quad (5)$$

From this calculation it follows that one RU covers less than 23% of the area, and the average time of arrival of the unit at the place of call will be:

$$\bar{\tau}_{прям} = -20{,}799 \cdot 0{,}2275 + 35{,}46 = 30{,}73 \text{ min}. \quad (6)$$

For one unit, the average travel time to the place of call exceeds the allowable value of 20 minutes, so it is necessary to increase the number of units. Calculate the coverage ratio of two RUs of Blyznyukivskyi district (Fig. 1):

$$k_{cover} = \frac{2 \cdot 314}{1380} = 0{,}4551. \quad (7)$$

From Fig. 1 we see that the unit also covers the neighboring area, so the coverage ratio should be less than 0,4551. Determine the average time of arrival of the RUs to the place of an emergency (dangerous event):

$$\bar{\tau}_{прям} = -20{,}799 \cdot 0{,}4551 + 35{,}46 = 25{,}99 \text{ min}. \quad (8)$$

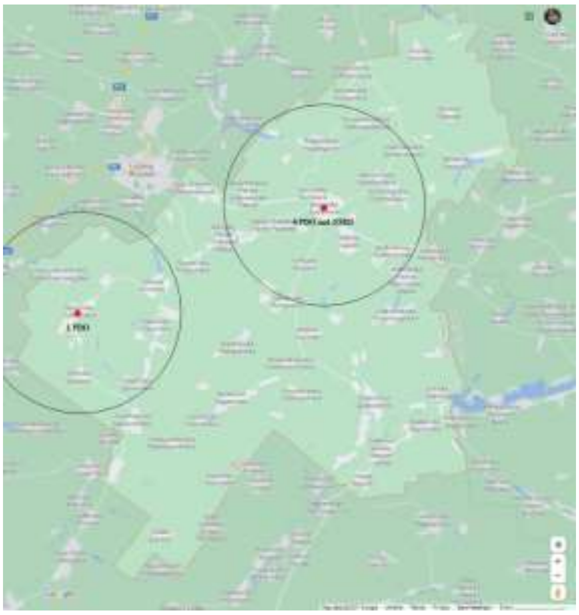

Fig. 1. Location of two fire depots in Blyzniukivskyi district of Kharkiv region

The first depot for the location of the RUs was located in the town Blyznyuky, as the level of danger there is the highest (this follows from the number of potentially dangerous objects (PDOs) and objects of increased danger (OsID)), the second depot – in the village. Samiilivka, because there is also an increased level of danger due to the presence of PDOs. Given the fact that with two RUs time of arrival still exceeds the minimum standard value of 20 minutes. Therefore, it is necessary to increase the number of depots. The third fire station should be located in the village Dobrovillya, because it is home to the maximum number of people in the united territorial community, which remained uncovered by the area of departure of the RU (Fig. 2).

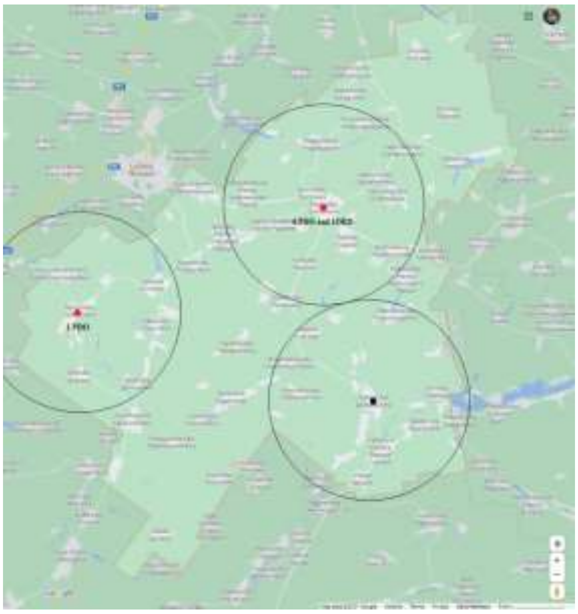

Fig. 2. Location of three fire depots in Blyzniukivskyi district of Kharkiv region

Calculate the coverage ratio and time of arrival of the unit when placing three fire depots in Blyzniukivskyi district:

$$k_{\text{cov}\,er} = \frac{3 \cdot 314}{1380} = 0{,}6826, \tag{9}$$

$$\bar{\tau}_{arrive} = -20{,}799 \cdot 0{,}6826 + 35{,}46 = 21{,}26 \text{ min.} \tag{10}$$

Since the average time of arrival of RUs to the place of call still exceeds the normative value, it would be advisable to create a fourth depot. It is most effective to place it in the village. Katerynivka (Fig. 3). Calculate the coverage ratio and time of arrival of RUs when placing four fire depots in Blyzniukivskyi district:

$$k_{\text{cov}\,er} = \frac{4 \cdot 314}{1380} = 0{,}9812\,, \tag{11}$$

$$\bar{\tau}_{arrive} = -20{,}799 \cdot 0{,}9812 + 35{,}46 = 15{,}05 \text{ min.} \tag{12}$$

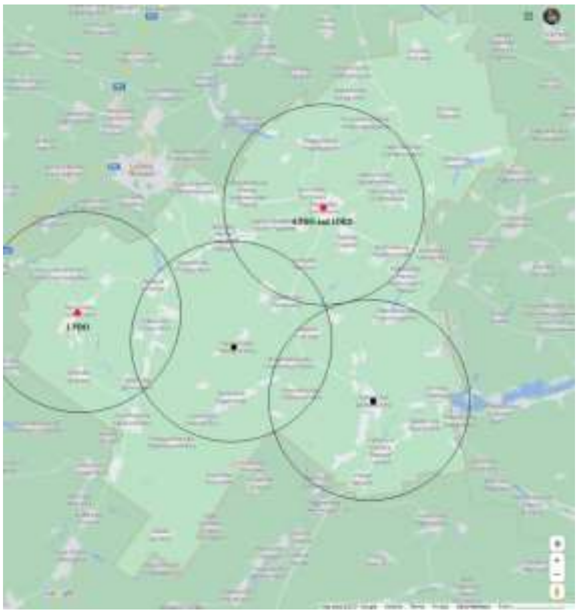

Fig. 3. Location of four fire depots in Blyzniukivskyi district of Kharkiv region

If there are four fire depots, the travel time will be reduced by 51%, given that in fact in this area there is one fire depot in the town Blyznyuky.

From Fig. 3 it can be seen that the service areas of fire and rescue units cover some area twice, so the actual coverage ratio will be less than the estimated. It is also necessary to take into account the following limitations of the mathematical model of emergency risk management [12] when placing these units:

1) the minimum area of intersection of the areas of operation of the PDP in a given area;

2) the affiliation of the areas of operation of the PDP;

3) the minimum area of intersection of the areas of operation of the PDP with the areas of prohibition;

4) the affiliation of the ATS and PNO of the area of intersection of the areas of operation of the PRP, providing response to the accident (fire) and the ATS or PNO in accordance with the call number;

5) the time of arrival of the PRP to the most remote point of the departure area, should not exceed the specified;

6) placement of PRP is carried out taking into account the limited resources.

Given the above restrictions, as well as the existing network of roads, the exit area of the PDP will be a bunch of broken lines (Fig. 4).

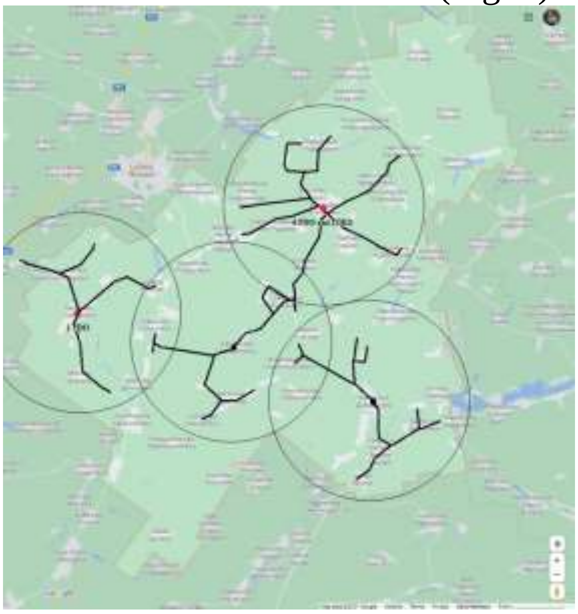

Fig. 4. Departure areas of three fire depots in Blyzniukivskyi district of Kharkiv region

To determine the service area, it is necessary to build a convex shell for tying broken, which allows you to get a polygon (Fig. 5), which is the actual area of departure, taking into account all the above limitations.

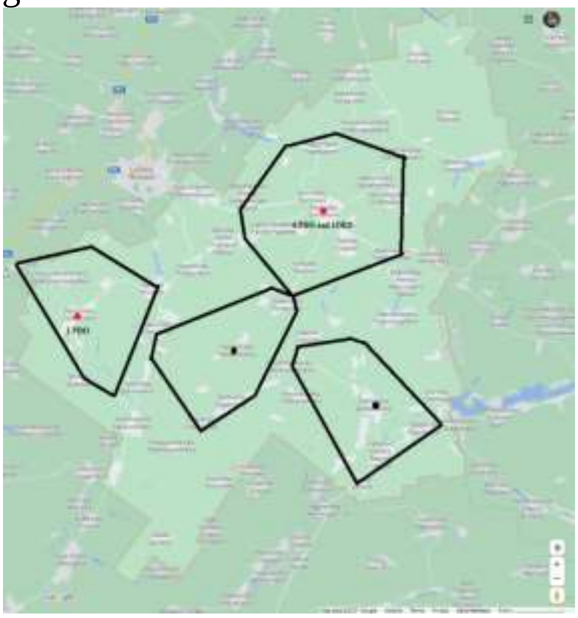

Fig. 5. Departure areas of three fire depots in Blyzniukivskyi district of Kharkiv region

Based on Fig. 5 it can be concluded that the coverage area, as well as the coverage ratio, will decrease compared to the coverage of circles of the corresponding radius. That is why the average travel time of the PRP to the place of occurrence of a dangerous event will exceed 15 minutes.

Since Blyzniukivskyi district is a region of Kharkiv region, which is part of the second cluster [12], we build a graph of the dependence of the integrated risk on the time of the unit to the place of call (Fig. 6).

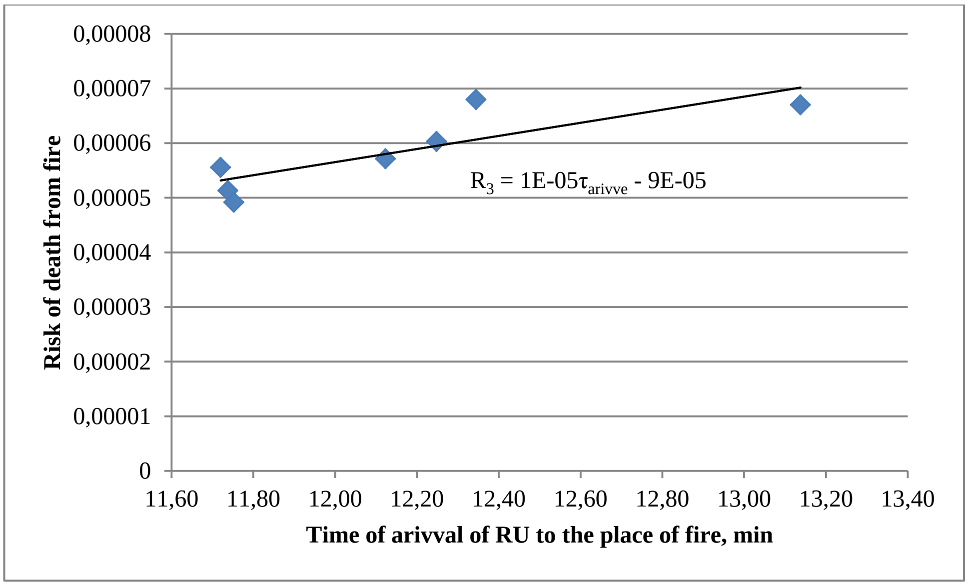

Fig. 6. Dependence of the integrated fire risk R_3 on the time of the RDP τ_{arrive}

We calculate the value of risk in Blyzniukivskyi district when placing the 1st, 2nd, 3rd and 4th fire depots:

$$R_3^1 = 10^{-5} \cdot 30{,}73 - 9 \cdot 10^{-5} = 2{,}173 \cdot 10^{-4}; \quad (13)$$

$$R_3^2 = 10^{-5} \cdot 25{,}99 - 9 \cdot 10^{-5} = 1{,}699 \cdot 10^{-4}; \quad (14)$$

$$R_3^3 = 10^{-5} \cdot 21{,}26 - 9 \cdot 10^{-5} = 1{,}226 \cdot 10^{-4}; \quad (15)$$

$$R_3^4 = 10^{-5} \cdot 15{,}05 - 9 \cdot 10^{-5} = 6{,}05 \cdot 10^{-5}. \quad (16)$$

Comparing the obtained data, we can conclude that with the increase in the number of fire depots, the integrated risk decreases. Thus, in the presence of 4 fire depots, the travel time to the place of call is reduced by 51%, and the corresponding risk - by 72%.

Conclusion. The paper minimizes the integrated risk of emergencies (dangerous events) by increasing the number of fire depots on the example of Blyzniukivskyi district of Kharkiv region. Departure areas are shown on a real map in Google Maps. Departure areas of fire and rescue units are convex polygons, the vertices of which depend on the road network. As a result of the increase from the 1st fire station to 4, the response time to the fire will be reduced by 51%, and the corresponding risk of an emergency will be reduced by 72%.

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МІНІМІЗАЦІЇ ІНТЕГРАЛЬНОГО РИЗИКУ НАДЗВИЧАЙНОЇ СИТУАЦІЇ НА ПРИКЛАДІ БЛИЗНЮКІВСЬКОГО РАЙОНУ ХАРКІВСЬКОЇ ОБЛАСТІ

Бордюженко С.Я., Данілін О.М., Стельмах О.А.

В роботі показано обернену залежність між коефіцієнтом покриття області і часом прямування на надзвичайну ситуацію (небезпечну подію). Під час збільшення кількості пожежних підрозділів час прибуття оперативно-рятувальних ситу буде зменшуватися, що безпосереньо впливає на зменшення інтегрального пожежного ризику. Саме тому при наявності фінансування кількість пожежних підрозділів може бути збільшена. Реалізовано мінімізацію інтегрального ризику надзвичайних ситуацій (небезпечних подій) за рахунок збільшення кількості пожежних депо на прикладі Близнюківського району Харківської області. Продемонстровано райони виїзду на реальній карті в Google Maps. Вибір додаткового пожежного підрозділу для зменшення інтегрального ризику включає в себе такі обмеження: мінімум площі перетину районів функціонування ПРП в заданій області; належність районів функціонування ПРП; мінімум площі перетину районів функціонування ПРП з областями заборони; належність ОПН та ПНО області перетину районів функціонування ПРП, що забезпечують реагування по аварію (пожежу) та ОПН або ПНО відповідно до номеру виклику; час прибуття ПРП до найвіддаленішої точки району виїзду, має не перевищувати заданого; розміщення ПРП здійснюється з урахуванням обмеження ресурсів. Райони виїзду пожежно-рятувальних підрозділів являють собою опуклі багатокутники, вершини яких залежать від сітки доріг. В результаті збільшення з 1-го пожежного депо до 4-х, час реагування на пожежу знизиться на 51 %, а відповідних ризик надзвичайної ситуації зменшиться на 72 %. Під час збільшення кількості пожежних підрозділів скоротиться час прибуття оперативно-рятувальних груп, що безпосередньо впливає на зниження сукупного пожежного ризику. Тому за наявності фінансування кількість пожежних частин можна збільшити.

Ключові слова: інтегральний ризик надзвичайної ситуації, коефіцієнт покриття, час прямування, область покриття, пожежно-рятувальний підрозділ, пожежне депо.

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