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DETERMINATION OF THE FIRE UNITS' LOCATION TAKING INTO ACCOUNT TRAFFIC CONGESTION

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In article critical influence of arrival time of saving divisions to the place of emergency is proved. The analysis of the applied methods of definition of dislocation of fire divisions in the city and in territories is carried out. The approach allowing to consider influence of a state and traffic congestion on arrival time of saving divisions to the place of emergency is offered. Practical application of this research will allow to reduce the number of the victims and material damage from emergency.
Keywords: *dislocation, fire brigade, emergency, arrival time of saving division, traffic congestion*.

ОПРЕДЕЛЕНИЕ МЕСТОНАХОЖДЕНИЯ ПОЖАРНЫХ ПОДРАЗДЕЛЕНИЙ С УЧЕТОМ ЗАГРУЖЕННОСТИ ДОРОГ

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В статье обосновано критическое влияние времени прибытия спасательных подразделений на место ЧС. Проведен анализ применяемых методов определения дислокации пожарных подразделений в городе и на территориях. Предложен подход, позволяющий учитывать влияние состояния и загруженности дорог на время прибытия спасательных подразделений к месту ЧС. Практическое применение этого исследования позволит сократить количество жертв и материальный ущерб от ЧС.
Ключевые слова: *дислокация, пожарная часть, ЧС, время прибытия спасательного подразделения, загруженность дорог*

Introduction

The fire is one of the most widespread emergency situations types today. Every year human activity becomes complicated that leads at its violations to serious social and economic consequences.

Annually the fires claim the people lives and cause extensive damage, and in certain cases lead to large-scale accidents. According to Head department of the public fire service of Emercom of Russia for 2017 there were 133077 fires in Russia in which 7824 persons died, 8796 persons are injured, 34191 structures are destroyed and the direct material damage of 14217273000 rubles is caused.

1. The problem state

In modern time the fire is one of the most widespread types of emergency situations. Human activity becomes complicated every year that leads at its violations to serious social and economic consequences.

Annually the fires claim the lives of people and cause extensive damage, and in certain cases lead to large-scale accidents. According to Head department of the public fire service of Emercom of Russia for 2017 in Russia there were 133077 fires in which 7824 persons died, 8796 persons are injured, 34191 structures are destroyed and the direct material damage of 14217273000 rubles is caused.

1. Condition of a problem

On statistical data most often death of people occurs at the first minutes of fire development before the firefighters arrival. Statistical data are reflected in the diagram of distribution of the fire victims on the death moment (fig. 1).

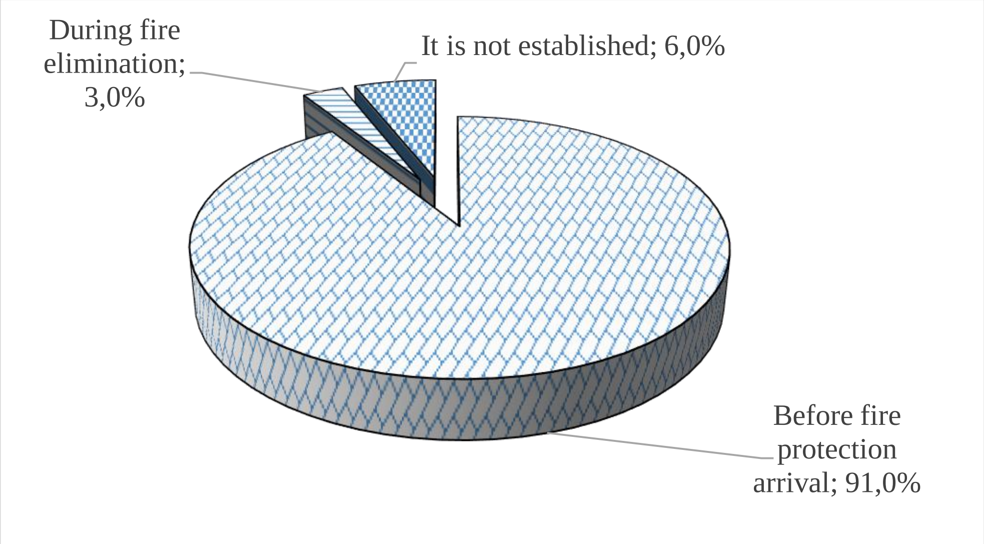


Fig. 1. Distribution of the fire victims on the death moment

Distribution of the main reasons for death on the fire are presented on diagram (fig. 2). One of the main causes of death of people is influence of dangerous factors of the fire. Time of death depends on composition of construction and finishing materials, however, as a rule death comes before arrival of rescuers. Therefore major role in reduction of number of the victims and material damage from the fire is played by arrival time of divisions of fire protection to the place of the fire.

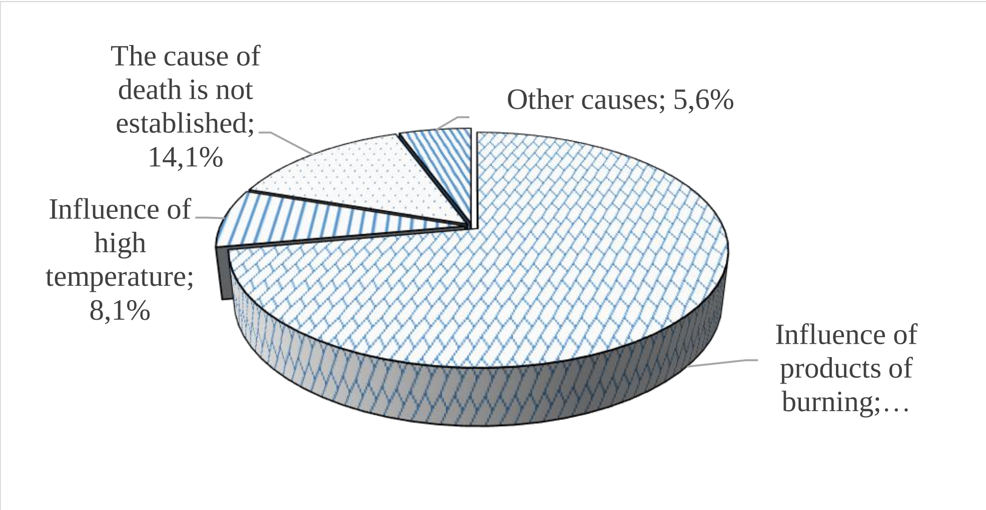


Fig. 2. Main reasons for death

Diagrams of risk distribution of people's death on the fires depending on arrival time of firefighters to the place of the fire and distribution of the average damage falling on one fire in the inhabited sector depending on arrival time of firefighters to the place of the fire are performed in the figures of 3 and 4.

Graphic model of development and fire extinguishing (fig. 5) allows to analyse the main stages of fire extinguishing from the point of view of time expenditure and to reveal "bottlenecks".

Arrival time of fire protection divisions on the fire depends on various reasons. The major factors defined at design emergency and rescue services in the cities and territories is the arrangement of fire brigades and equipment by their fire fighting equipment. The quantity and an arrangement of fire brigades is defined according to the normative document of the joint venture 11.13130.2009 Places of dislocation of fire protection divisions. Order and technique of definition. (Location of fire service divisions. Procedure and methods of determination).

For each considered object of the alleged fire in the territory of the settlement or a production object is determined by the size of the most admissible distance the spatial zone of admissible placement of fire protection division (fire station). Thereby the territory of potentially possible dislocation of division of fire protection for protection of the considered object of the alleged fire is defined.

Generally, the most admissible distance from object of the alleged fire to the next fire station should be determined by street network of roads of the settlement or a production object.

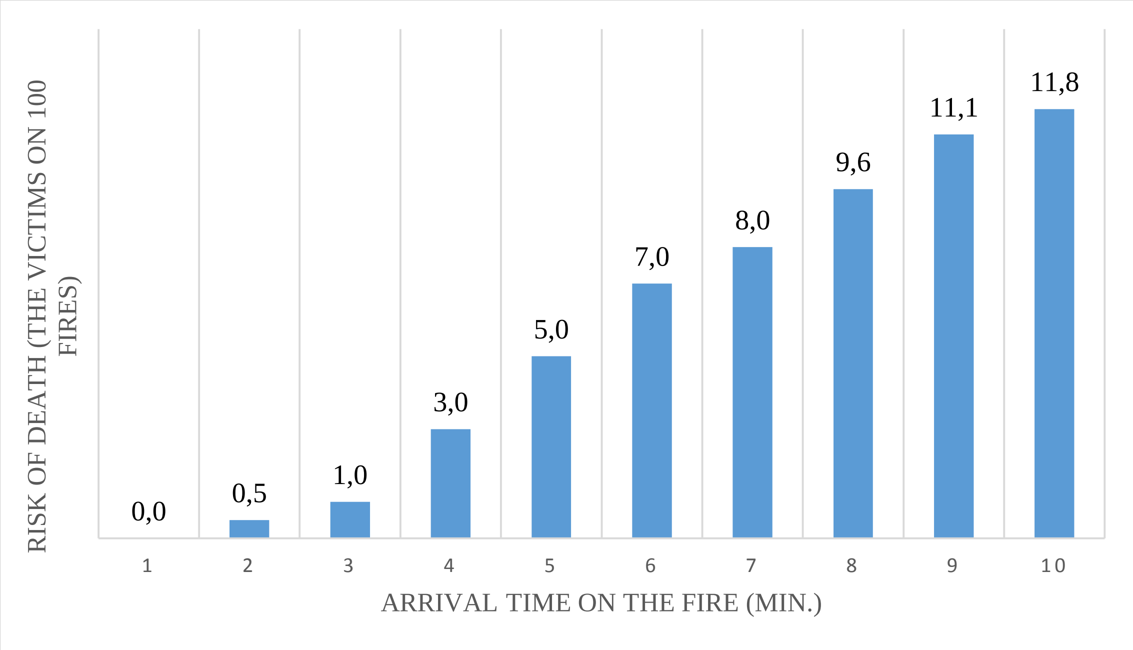


Fig. 3. Risk distribution of people's death on the fires depending on arrival time of firefighters to the place of the fire

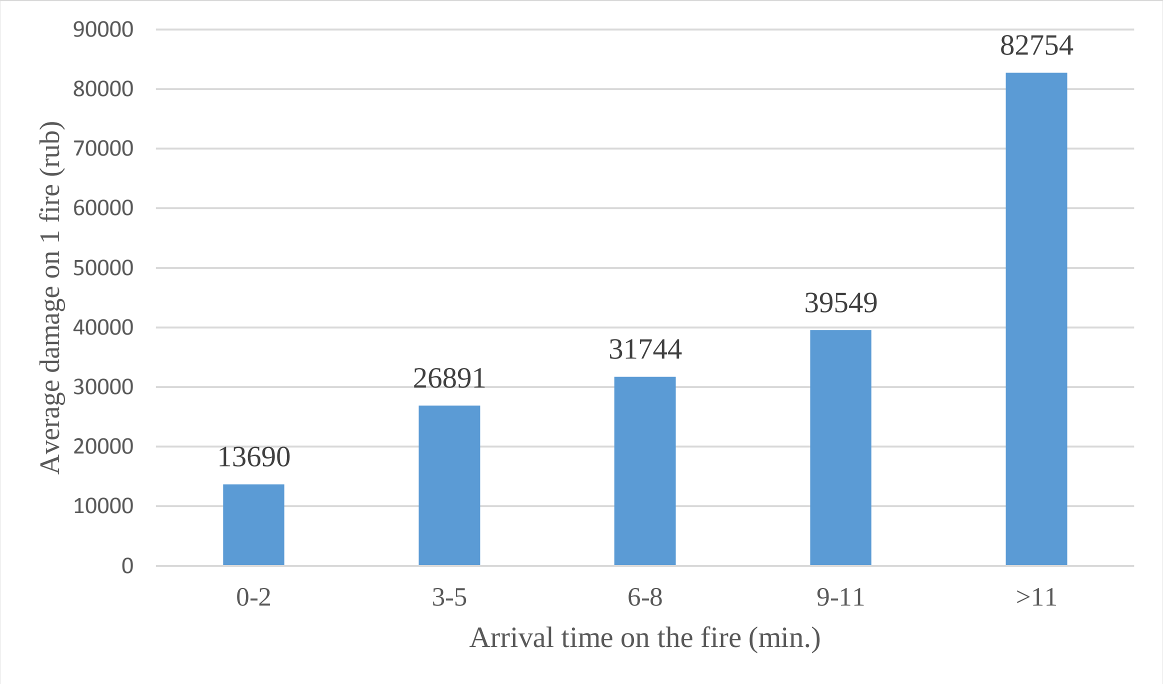
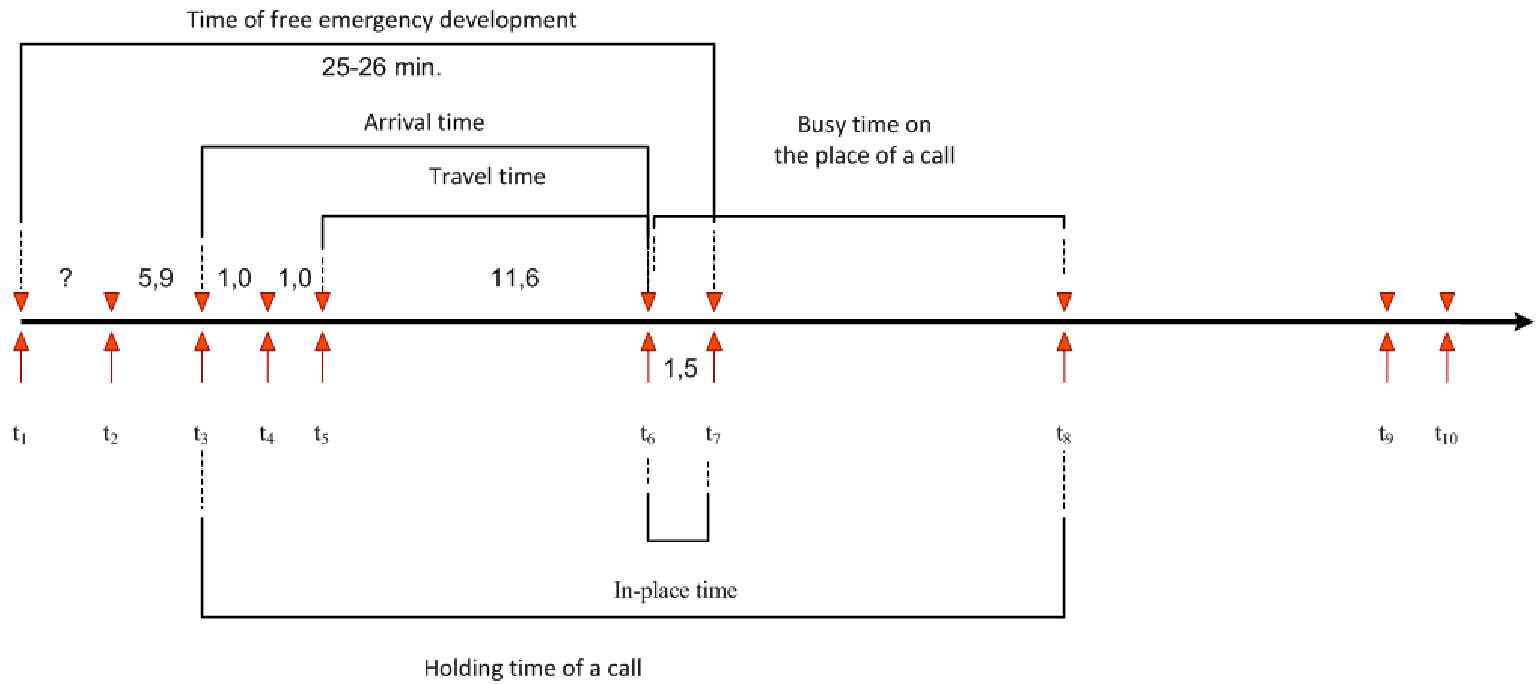


Fig. 4. Distribution of the average damage falling on one fire in the inhabited sector depending on arrival time of firefighters to the place of the fire



t_1 - emergency emergence moment;
t_2 - emergency detection moment;
t_3 - the moment of the message about emergency on control office of a fire service
t_4 - moment of command receipt for departure;
t_5 - the moment of departure of the fire service divisions to the place of a call;
t_6 - the moment of arrival of the fire service divisions to the place of a call;
t_7 - the moment of departure of the fire service divisions from the place of a call;
t_8 - the arrival moment of the fire service divisions to the dislocation place;
t_9 - the placement moment of the fire service divisions in combat crew.

Fig. 5. Graphic model of development and fire extinguishing

For creation of a spatial zone of potentially possible placement of the fire station in the form of a simple geometrical figure it is allowed to use not the most admissible distance, but the radius of the circle described around a spatial zone (distance on an air straight line from object of the alleged fire to the potential location of the fire station), calculated taking into account coefficient of not straightforwardness of street network of roads in the settlement or on a production object.

However really arrival time of fire service is influenced not only geometrical by an arrangement of street network of roads, but also a set of other factors, such as load and passability of the road depending on time of day, a season and road condition. Authors have offered approach for accounting of these factors.

2. Problem solving methodology

The methods of transport logistics had been used to solve the problem. The process of solving of transport logistics optimization problems involves carrying out the deep analysis and taking account a significant amount of factors that are impossible without the use of mathematical apparatus and information technologies. The authors have analyzed the known mathematical methods applied in logistics [5–7].

The transport task and routing problems models are the main points in solving the tasks of freight automobile transportation operational planning.

The economic-mathematical model of a classical transport task is presented in general terms using (1) – (5) [8]:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}\cdot x_{ij} \to \min . \quad (1)$$

$$\sum_{i=1}^{n} x_{ij} = a_i \left(i = \overline{1,n} \right). \quad (2)$$

$$\sum_{j=1}^{m} x_{ij} = b_j \left(j = \overline{1,m} \right). \quad (3)$$

$$\forall x_{ij} \geq 0 . \quad (4)$$

$$\sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j . \quad (5)$$

where *i* is the suppliers number; *j* is the consumers number; *n* is the departure points number; *m* is the destinations number; a_i is the restrictions on the offer, i.e. production stock in the point of departure A_i; b_j is the restrictions on demand, i.e. demand for production in the destination B_j; c_{ij} is the criterion function elements; x_{ij} is a production transported quantity from the point of departure A_i to the destination B_j.

In the considered model it is supposed that total stocks are equal to the total requirements using (5). In the closed model of a transport task stocks and requirements are equal, otherwise the model is open. For the open model two cases are considered if total stocks exceed the total requirements (6) and the total requirements exceed the total stocks (7):

$$\sum_{i=1}^{n} a_i > \sum_{j=1}^{m} b_j . \quad (6)$$

$$\sum_{i=1}^{n} a_i < \sum_{j=1}^{m} b_j . \quad (7)$$

The solution of transport tasks on the basis of the open model is carried out by its reduction to the closed model. If the total stocks exceed the total requirements (6), the fictitious consumer whose requirement is determined using (8) is added:

$$B_{n+1} = \sum_{i=1}^{n} a_i - \sum_{j=1}^{m} b_j . \quad (8)$$

Otherwise, when the total requirements exceed the total stocks (7), the fictitious supplier whose stocks are determined using (9) is added:

$$A_{m+1} = \sum_{j=1}^{m} b_j - \sum_{i=1}^{n} a_i . \quad (9)$$

Minimum of transport work in ton-kilometers, expenses of time or of the transportation cost is criteria of optimality in a transport task. All three parameters depend on the distance passed by the vehicle. The first criterion is determined using (1). The second criterion is counted as the sum of the ratio of the distance passed by each vehicle to its average speed. The value of the third criterion is calculated using (10)

$$P = (a + bS)\times Q, \quad (10)$$

where *P* is the costs necessary for transportation of freight on the set distance; *a* is the constant expenses necessary for performance of a certain volume of transportations; *b* is variable costs for one kilometer; *S* is transportation distance; *Q* is the volume of transportations.

Thus, irrespective of the chosen criterion of optimality it is necessary to define the distance passed by the vehicle.

For the solving of transport tasks broad application was found by a distributive method. It has several versions which, generally differ in the way of detection of the optimal solution. Three methods are the most known. They are methods of Khichkov, Kreko and the modified distributive method or a method of potentials, refer to [8].

The method of potentials allows solving a transport problem for finite number of iterations, starting with some basic plan of transportations.

On the basis of the known models of transportation analysis it is established that the route of freight delivery is estimated at them only on the distance passed by the vehicle. At the same time the set of the factors which are also influencing time of delivery of freight such as a type of the vehicle, intensity of a transport stream, road capacity, weather and seasonal conditions, day time and others aren't considered. In this regard the creation of the mathematical model considering influence of the specified factors for the period of cargo delivery gains the special importance.

3. Development of the optimum route choice model

The choice and use of rational routes at strict observance of deliveries terms help to achieve not only operational expenses minimization, but also to reduce the commodity and the production stocks in warehouses by 1.5-2 points. Therefore, the special relevance is gained by the works allowing calculating precisely volumes of a cargo transportation, to count quantity of transport units necessary for providing flow of cargo, to define rational routes of the movement, and also to reduce total costs of transportation.

For creation of such model it is inexpedient to refuse the known well worked economic-mathematical methods. It is only necessary to modify them to increase their accuracy due to introduction of additional parameters. The concepts "fictitious distance" formula (S_{fi}) and "conductivity of the road segment" (G_i) by analogy with the electric conductivity are introduced for this purpose [9-12]. In the known methods of the minimum element and potentials applied consistently at the solution of a transport task we replace the real distance by the fictitious one. The fictitious distance (S_{fi}) is the distance which the k-th vehicle could pass during time of passing the real distance along the good road with the maximum admissible speed (Fig. 1). Value of S_{fi} is determined by (10-12). Conductivity (G_i) shows, how many time the speed of the vehicle movement on the i-th road segment is reduced in comparison with the maximum admissible speed, allowed by traffic regulations, owing to poor quality of the road (13).

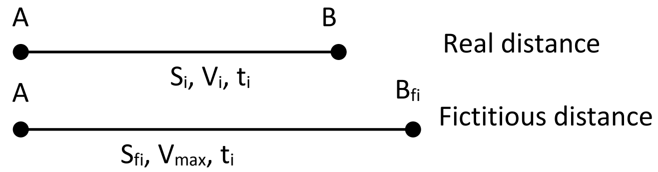


Fig. 1. Transformation of the real distance into the fictitious one

S_i is i-th uniform road segment possessing a certain traffic capacity;

V_i is actual average speed vehicle on i-th road segment;

t_i is real time spent by vehicle on the i-th road segment;

S_{fi} is fictitious distance (fictitious length of the i-th road segment);

V_{max} is the greatest possible speed of the vehicle which doesn't exceed the speed allowed by traffic regulations.

The real time spent by the vehicle on the i-th road segment (t_i) is determined using (11):

$$t_i = S_i / V_i \quad , \qquad (11)$$

The time which the vehicle had to spend passing the fictitious distance is defined using (12):

$$t_i = S_{fi} / V_{max} \quad . \qquad (12)$$

t_i=const, therefore:

$$S_{fi} / S_i = V_{max} / V_i \quad , \qquad (13)$$

$$G_i = V_{max} / V_i \quad . \qquad (14)$$

The greatest possible speed of the vehicle which doesn't exceed the speed allowed by traffic regulations on the i-th road segment (V_{max}) is defined using (15):

$$V_{max} = \begin{cases} V_k, & \text{if } V_k \le V_{tr} \\ V_{tr}, & \text{if } V_k > V_{tr} \end{cases} , \qquad (15)$$

where V_{tr} is the most admissible speed determined by traffic regulations on the considered road segment; V_k is the maximum speed which k-th vehicle is able to reach.

By means of the navigation satellite system (GPS) data on the speed allowed by traffic regulations for the i-th road segment are defined.

"The fictitious distance" (S_{fi}) can be calculated using (16):

$$S_{fi} = S_i / G_i \, , \qquad (16)$$

The mathematical model of the optimum route choice M_{orc} can be presented in the form of the following set:

$$M_{orc} = \{O, V_{inp}, V_{out}, P\} \; , \qquad (17)$$

where O is the object of modeling (process of the choice of an optimum route); V_{inp} is a set of input parameters (set of routes); V_{out} is a set of output parameters; P is a transformation rule (transformation of qualitative parameters into quantitative ones).

We will determine parameters of mathematical model.

Three parameters are entrance (18):

$$V_{inp} = \{M, S, G_i\} \; , \qquad (18)$$

where M is a set of routes; S is the route length; G_i is "conductivity" (road capacity) of the i-th road segment;

The criterion of the road capacity ("conductivity") of the i-th road segment has a complex structure. Its components (the road quality and the intensity of transport stream intensity) belong to the various types of data (qualitative, quantitative):

$$G_i = \{K_{rq}, K_{it}\}\ , \quad (19)$$

where K_{rd} is a criterion characterizing the road quality, it is determined using(20); $K_{it}$is a criterion characterizing intensity of a transport stream in dependence on day time and season (21).

$$K_{rq} = \{K_{iee}, K_{om}\}\ , \quad (20)$$

where K_{iee} is the indicator of the engineering equipment and arrangement of the road; K_{om} is the indicator of operational maintenance of roads.

$$K_{it} = f(S_z, t_d)\ , \quad (21)$$

where S_z is the coefficient of a seasonal interval; $t_d$is a time interval coefficient.

Function $f(S_z, t_d)$is presented by the tabular dependence delivered experimentally for *i*-th route segment with use of Global Navigation Satellite System (tab. 1, 2). Global Navigation Satellite System (GLONASS) is an analog of NAVSTAR GPS. Information on coordinates, speed, traffic jams congestion can be retrieved from GLONASS

Output parameters are presented using (22)

$$V_{out} = \{S_f\}\ , \quad (22)$$

where S_f is estimated function for each route.

The equation (23) describes transformation rules of qualitative criteria into quantitative ones:

$$G_i = K_{rq} \cdot K_{it}, \quad (23)$$

Conductivity G_i=[0,1] is a dimensionless quantity.

$$K_{rq} = K_{iee} \cdot K_{om}, \quad (24)$$

Indicators K_{iee}, K_{om} define the quality and the condition of the road. K_{iee} is the indicator of the engineering equipment and arrangement of the road. It shows compliance of basic elements of the engineering equipment and arrangement of roads to standard requirements. Protections, road signs, marking, crossings of highways with the automobile roads and the railroads, adjunctions, platforms of rest and bus-stops, walking paths and sidewalks in settlements, lighting are belong to basic elements of the engineering equipment and arrangement of the roads. K_{om} is an operational condition of the road which represents a degree of compliance of its variable indicators to the standard requirements. The elements defining an operational condition of the road are durability of road clothes, coupling qualities, flatness and a roughness of a covering, condition of the engineering equipment, condition of marking, actually used width of the carriageway and roadsides, etc. Standard values of coefficients of K_{iee} and K_{om} are taken according to the existing normative and technical documents. They are defined on the basis of the statistical researches conducted by Federal road agency of the Ministry of Transport of the Russian Federation "ROSAVTODOR".

The criterion of the road quality (K_{rd}) has numerical type of data. K_{rd}=[0,1].

Qualitative criteria K^f_{rq} and K^f_{iee} are used in the model. They are derived from coefficients K_{rd} and K_{iee} using (25) and (26).

$$K^f_{rq} = \begin{cases} emergency, & \text{if } 0 \le k_{rd} < 0.25 \\ unsatisfactory, & \text{if } 0.25 \le k_{rd} < 0.5 \\ satisfactory, & \text{if } 0.5 \le k_{rd} < 0.75 \\ normal, & \text{if } 0.75 \le k_{rd} \le 1 \end{cases} \quad (25)$$

The standard value of the engineering equipment and the arrangement indicator (K_{iee}) take the value equal to the unit.

$$K^f_{iee} = \begin{cases} meets\ stsndart, & \text{if } 0.9 \le k_{iee} \le 1 \\ unacceptable\ state, & \text{if } 0 \le k_{iee} \le 0.9 \end{cases} \quad (26)$$

Value of coefficient of K_{om} is determined by the results of assessment of the actual level of maintenance of the road during the last year.

$$K^f_{om} = \begin{cases} emergency, & \text{if } 0 \le k_{om} < 0.25 \\ unsatisfactory, & \text{if } 0.25 \le k_{om} < 0.5 \\ satisfactory, & \text{if } 0.5 \le k_{om} < 0.75 \\ normal, & \text{if } 0.75 \le k_{om} \le 1 \end{cases}, \quad (27)$$

$$K_{it} = S_z \cdot t_d\ . \quad (28)$$

Coefficients S_z and t_d from (21) are calculated on the basis of the statistical data obtained by Global navigation satellite system (GLONASS system) using (29) and (30). The data obtained as a result of the preliminary experiment made during 5 days of every season on the uniform by state highway segment, are presented in tables I and II.

$$S_z = V_{avg} / V_{\max}\ , \quad (29)$$

$$t_d = V_{avg} / V_{\max}\ , \quad (30)$$

where $V_{\max}$ is the greatest possible speed on the road segment (in this particular case $V_{\max}$=90 km/h); V_{avg} is an average speed on the road segment, is determined by (31) according to the tables I and II. The data for (29) are given in the table I, for (30) in the table II.

$$V_{avg} = \sum_{i=1}^{n} V_i \Big/ n\ . \quad (31)$$

Table 1

Information for the season coefficient

Seasons	*Speed on the studied road segment (km/h)*				S_z
	1	2	*n*	V_{avg}	
Summer	90	87	90	89	0,99
Autumn	87	75	84	82	0,91
Winter	75	65	70	70	0,78
Spring	87	80	85	84	0,93

Table 2

Information for the coefficient of time interval of days

Time interval	*Speed on the studied road segment (km/h)*				t_d
	1	*2*	*n*	V_{avg}	
00.00–06.00	90	90	87	89	0,99
06.00–08.00	85	87	80	84	0,93
08.00–10.00	77	78	75	77	0,85
10.00–17.00	82	84	76	81	0,90
17.00–19.00	77	78	75	77	0,85
19.00–00.00	88	87	86	87	0,97

The experiment with use of GLONASS system has been made for the check of model adequacy. Cardinality of sample rate of N is very big. It is defined by intensity of the transport stream. Therefore, research was carried out on representative sampling by cardinality of n: n<N. Sample units are formed as follows: necessary information was gathered from 20 route segments of cargo delivery, uniform in a state, with use of GLONASS system during 5 days randomly chosen of every season. In the course of experiment measurements from 20 routes a day on each route segment was performed. Thus, the cardinality of selection of n made 8000 data sets.

The created sample units were used for calculation of coefficients and applied to definition of a route optimality criterion.

The method of calculation of the transport task coefficients of S_z and t_d taking into account the entered concepts consists in the following. As an indicator of optimality criterion of c_{ij} we used the sum of fictitious distances of the uniform segments of this route calculated by (16) using conductivity. The condition of optimality was determined using (1).

For calculation of conductivity of the *k*-th route segment G_k it is necessary to define coefficients K_{iee}, K_{om}, S_z and t_d. Coefficients K_{iee}, *Kom* are determine by results of the assessment of the engineering equipment and arrangement of the road and the real level of maintenance of the road for the last year. Coefficients S_z and *td* are calculated on the basis of the statistical data obtained by GLONASS system using (29), (30).

For the assessment of the road condition qualitative criteria K^f_{rq}, K^f_{iee} and K^f_{om} delivered using (25–27) are made.

Then it is necessary to calculate the criterion characterizing intensity of the transport stream depending on day time and a season of K_{ip} by (19) and criterion of the road quality of K_{rd} using (23). Conductivity is determined using (22). The fictitious distance of the route segment is calculated using (15).

When all fictitious distances of the uniform route segments are known, the criterion of this route optimality c_{ij} is calculated as the sum of fictitious distances of the uniform segments of this route. Then consistently we apply the known methods of the minimum element and potentials, having replaced real distance by fictitious. If the model is opened, we transform it to the closed one.

Gradually the database will be replenished and updated. The authors recommend to update the data once in three years.

4. Conclusion

The choice and the use of rational routes with strict observance of the deliveries terms help to achieve not only minimization of operational expenses, but also to reduce commodity and production stocks in warehouses by 1.5–2 points. Therefore, the special relevance is gained by the works allowing to calculate precisely volumes of cargo transportation, to count quantity of transport units necessary for providing the cargo flow, to define rational routes of the movement, and also to reduce the total costs of transportation.

On the basis of the analysis of the known mathematical methods applied in transport logistics, the authors drew a conclusion that the route of freight delivery is estimated on the distance passed by the vehicle. However, the time of freight delivery depends not only on distance, but also on a set of other factors, such as vehicle type, road capacity, transport stream intensity, weather conditions, season and others.

For taking note of additional factors when a freight delivery route is optimizing the method of analogy and similarity is used by the authors. The movement parameters were described by analogy with an electric chain. For this purpose, the authors introduced new concepts a "fictitious distance" and a "conductivity of the road". The authors developed a mathematical model allowing to optimize the delivery of freight, taking into account not only distances, but also the probable speed of the vehicle movement depending on the road quality, transport stream intensity, weather conditions.

References

1. EU Logistics Action Plan. 2007. European Commission official site. Available at: http:// ec.curopa.cu/transport/logistics/indcx_cn.html. Date of access: 22.04.2016.
2. Logistics Performance Index. International LPI. World Bank official site. Available at: http://lpi.worldbank.org/international. Date of access: 27.04.2016.
3. Litman Todd. The New Transportation Planning Paradigm. ITE Journal. 2013. Vol. 83. 6. PP. 20–28. Available at: http://digitaleditions.sheridan.com/publication/?i=161624.
4. Litman Todd. Towards More Comprehensive and Multi-Modal Transport Evaluation. VTPI. Available at: http://www.vtpi.org/comp_evaluation.pdf. Summarized in JOURNEYS, September 2013. PP. 50—58 (www.ltaacademy.gov.sg/journeys.htm).
5. Anikina I.A., Shikul'skaya O.M. Analysis of the Methods, Models and Algorithms Applied in Logistic Researches. Caspian Magazine: Management and High Technologies. 2012. 1 (17). PP. 82—87. (In Russian)
6. Benedetto Barabino, Sara Salis, Bruno Useli. Fare Evasion in Proof-Of-Payment Transit Systems: Deriving the Optimum Inspection Level. Transportation Research Part B: Methodological. 2014. Vol. 70. PP. 1—17. DOI: http://dx.doi.org/10.1016/j.trb.2014.08.001.
7. Jiwon Kim, Hani S. Mahmassani. Compound Gamma Representation for Modeling Travel Time Variability in a Traffic Network. Transportation Research Part B: Methodological. 2015. Vol. 80. PP. 40–63. DOI: http://dx.doi.org/10.1016/jtrb.2015.06.011.
8. Шикульская О. М., Есмагамбетов Т. У. Решение оптимизационных задач транспортной логистики с учетом состояния и загруженности дорог // Вестник МГСУ. 2015. № 12. С. 160–173. (In Russian)
9. Shikulskaya O. M., Nezametdinova É. R. Modernization of a conceptual model of a data bank for physicotechnical effects based on contemporary information technology // Springer New York / Measurement Techniques. Vol. 50. № 1 / January. 2007. PP. 7–9. ISSN 0543-1972 (Print) 1573-8906 (Online), doi: 10.1007/s11018-007-0013-7
10. Petrova I., Shikulskaya O., Shikulskiy M. Conceptual modeling methodology of multifunction sensors on the basis of a fractal approach. Advanced Materials Research. 2014. Vol. 875–877. PP. 951–956. DOI: http://dx.doi.org/10.4028/www.scientific.net/AMR.875-877.951.
11. Zaripova V., Petrova I. System of Conceptual Design Based on Energy-Informational Model. Progress in Systems Engineering, Proceedings of the 23rd International Conference on Systems Engineering. August, 2014, Las Vegas, NV, Series: Advances in Intelligent Systems and Computing, 2015. Vol. 330. PP. 365–373. DOI: http://dx.doi.org/10.1007/978-3- 319-08422-0_54
12. Anufriev D. P., Shikulskaya O. M., Esmagambetov T. U.The optimization model of transport routes taking into account the state of roads and road traffic congestions // IEEE International Conference on Industrial Engineering and Engineering Management Сер. "2016 International Conference on Industrial Engineering and Engineering Management, IEEM 2016" 2016. С. 1717–1721.

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Esmagambetov T. U., Gaber J., Shikulskaya O. M. Determination of the fire units' location taking into account traffic congestion // Инженерно-строительный вестник Прикаспия : научно-технический журнал / Астраханский государственный архитектурно-строительный университет. Астрахань : ГАОУ АО ВО «АГАСУ», 2018. № 1 (23). С. 44–52.