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Research article

THE ALGORITHMS FOR DRAWING UP ANNUAL PLANS OF INSPECTIONS PERFORMED BY ROSPOTREBNADZOR'S REGIONAL ORGANIZATIONS WITHIN THE FRAMEWORK OF RISK-BASED MODEL

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The existing model of control and surveillance activities is based on a procedure that involves assigning activities performed by juridical persons or private entrepreneurs and (or) production facilities used by them in these activities into a specific risk category or a specific hazard class (category). The goal of the present work was to develop and improve algorithms for drawing up annual plans of inspections performed by Rospotrebnadzor's territorial organizations within the framework of the risk-based model.

For the first time, we have formulated conceptual and mathematical statement of the problem of planning control and surveillance activities performed by Rospotrebnadzor. This allowed us, among other things, to consider history of violations (integrity of a given subject) over a specific period and availability of objects for inspections. The latter is described with several parameters that include both regional peculiarities (a distance between objects, quality of road networks) and "complexity" of checking a particular object. When analyzing the mathematical statement, we identified certain model parameters that had the greatest influence on a solution to the problem, that is, the most sensitive parameters that should be regulated with special care if we want to make control and surveillance activities more effective.

We have created planning algorithms with preset parameter values (scenario forecasting programs) and tested them at the regional level. We have developed three criteria for comparing these algorithms: coverage of a number of subjects that are to be inspected; coverage of a number of objects that are to be inspected; coverage by the total risk. The testing results indicate that the combined algorithm has higher coverage rates since in this case not all objects are inspected when a given subject is being checked. Consequently, this allows reducing overall labor costs required to perform an inspection.

The suggested approaches give an opportunity to achieve more effective distribution and use of resources allocated by Rospotrebnadzor for scheduled inspections.

Keywords: *planning algorithms, control and surveillance activities, economic entities, scheduled inspections, risk-based surveillance, hazard class, working hours fund, mathematical model.*

The risk-based approach is being actively implemented in the Russian Federation in various spheres [1–6], for example, state control in sea and river ports, state surveillance over industrial safety, customs administration, etc. Belarus and Kazakhstan have accumulated certain experience in implementing the risk-based approach into control and surveillance activities. The work [7] dwells on analyzing Russian practices of risk-based regulation and gives suggestions on how to develop its instruments. The authors pay special attention to risk-based regulation of the financial sector and risk regulation in the environmental protection and emergencies. The work [8] concentrates on applying risk-based procedures in tax administration. The authors of the work [9] describe both foreign and Russian experience in effective use of the risk-based approach when inspecting technical devices at oil and gas extraction facilities. A risk is assessed by creating a risk matrix (this matrix is based on a probability of an event and its "severity") that facilitates making

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effective and well-structured decisions. The paper [10] describes a methodical approach to risk-based surveillance over activities performed by lending institutions. The concept of the risk-based approach and its practical implementation are widely used in internal audit [11, 12]. The authors of the work [13] suggest a planning procedure for the risk-based approach as per key performance indicators. Use of the risk-based approaches in planning of control activities by surveillance bodies of the EMERCOM of Russia is presented in the work [14]. The paper [15] describes an optimal planning procedure for prevention within the HSE management system. A special procedure was developed for optimal planning of preventive activities; this procedure is based on minimization of any residual occupational risk taking into account preset technical and economic limitations. The work [16] dwells on contemporary procedures for planning activities aimed at strengthening security of critical facilities. These procedures rely on using program-target approaches. Besides, planning and organization of the public healthcare system in a situation when resources are limited are described in detail in the work [17]. Therefore, we can see that the risk-based approach is being widely used in multiple spheres.

The legislation in the RF stipulates rules for assigning activities performed by juridical persons and private entrepreneurs and (or) production facilities used by them in these activities into a certain risk category or into a certain hazard class (category). These rules are fixed in two documents: the RF Government Order issued on August 17, 2016 No. 806 "On application of the risk-based approach when organizing specific control (surveillance) activities and making alterations into some orders of the RF Government"[1] and the Methodical Guidelines MR 5.1.0116-17 "The risk-based model of control and surveillance activities in the sphere of providing sanitary-epidemiological welfare. Classification of economic entities, types of activity and objects under surveillance as per potential health risks for organizing scheduled control and surveillance activities"[2]. The existing model of control and surveillance activities is based on a procedure that involves assigning activities performed by juridical persons or private entrepreneurs and (or) production facilities used by them in these activities into a specific risk category or a specific hazard class (category). This category is determined as per potential health risk for people influenced by these economic activities [18].

In our previous works, we suggested an algorithm for planning control and surveillance activities. It was based on a procedure that involved stepwise adding of economic entities into a schedule, starting from those belonging to the 1st hazard category and up to depletion of all the allocated resources according to working time fund [19, 20]. It hardly seems optimal to use only one attribute (hazard class) when drawing up schedules of control and surveillance activities since this cannot provide sufficient coverage of economic activities performed by economic entities and production facilities used in these activities that should be inspected. Given that, use of any additional attributes when planning control and surveillance activities can make them more effective. Absence of any violations during a specific period (in case an economic entity is law-abiding) can be a potential additional attribute. It can be measured both as per a whole set of possible violations and as per isolated facts of violations (for example, specific measured indicators or chemicals). The second way to make planning of activities more effective is to reduce time allocated for one inspection, for example, by selecting priority objects and an optimal program of laboratory support.

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[1] O primenenii risk-orientirovannogo podkhoda pri organizatsii otdel'nykh vidov gosudarstvennogo kontrolya (nadzora) i vnesenii izmenenii v nekotorye akty Pravitel'stva Rossiiskoi Federatsii: Postanovlenie Pravitel'stva RF ot 17.08.2016 № 806 [On application of the risk-based approach when organizing specific control (surveillance) activities and making alterations into some orders of the RF Government: The RF Government Order issued on August 17, 2016 No. 806]. *GARANT: information and legal support*. Available at: https://base.garant.ru/71473944/ (February 25, 2022) (in Russian).

[2] MR 5.1.0116-17. Risk-orientirovannaya model' kontrol'no-nadzornoi deyatel'nosti v sfere obespecheniya sanitarno-epidemiologicheskogo blagopoluchiya. Klassifikatsiya khozyaistvuyushchikh sub"ektov, vidov deyatel'nosti i ob"ektov nadzora po potentsial'nomu risku prichineniya vreda zdorov'yu cheloveka dlya organizatsii planovykh kontrol'no-nadzornykh meropriyatii (utv. i vved. v deistvie Rukovoditelem Federal'noi sluzhby po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka, Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii A.Yu. Popovoi 11.08.2017 [The risk-based model of control and surveillance activities in the sphere of providing sanitary-epidemiological welfare. Classification of economic entities, types of activity and objects under surveillance as per potential health risks for organizing scheduled control and surveillance activities (approved and enacted by A.Yu. Popova, the Head of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing and the RF Chief Sanitary Inspector on August 11, 2017)]. *KODEKS: electronic fund for legal and reference documentation.* Available at: https://docs.cntd.ru/document/555601296 (February 25, 2022) (in Russian).

Given all that, it is necessary to develop more effective planning of control and surveillance activities bearing in mind both its theoretical and applied aspects including:

– developing algorithms for drawing up annual schedules of inspections that implement a differentiated approach to planning. This approach should consider a hazard class of activities performed by juridical persons and private entrepreneurs and (or) production facilities used in these activities;

– comparative analysis of the suggested algorithms in order to reveal the most rational decisions on activity planning.

The goal of the present work was to develop and improve algorithms for drawing up annual schedules of inspections performed by Rospotrebnadzor's territorial organizations in RF regions within the framework of the risk-based model. To achieve this goal, we solved the following tasks:

- we determined parameters of interaction between Rospotrebnadzor and economic entities within control and surveillance activities;
- we formulated conceptual and mathematical statement of the problem of planning control and surveillance activities performed by Rospotrebnadzor within scheduled inspections;
- we identified model parameters and examined a system of equations suggested within the mathematical statement of the problem to detect sensitivity to changes in parameters;
- we developed planning algorithms with preset parameter values (scenario forecasting programs) and tested them at the regional level within the risk-based model.

Materials and methods. We used system analysis, mathematical modeling, statistical and regression analysis in our study.

Overall, Rospotrebnadzor has a complicated hierarchical structure. In this work, we concentrated on control and surveillance activities performed by Rospotrebnadzor's territorial organizations and their branches. To determine parameters of Rospotrebnadzor facilities, it is advisable to consider several following characteristics of the surveillance service. They are a number of workers who participate in scheduled control and surveillance activities according to an organizational chart as per specific divisions (surveillance sectors); laboratory facilities (a number of workers, a number of tests as per factors). Economic entities are identified as per the following parameters: a potential health risk as per types of economic activities, production facilities; a share (frequency) of detected violations as per economic activities or production facilities; a hazard category of an economic entity; a hazard category as per an economic activity; a hazard category as per production facilities; periodicity of inspections; the date of the latest inspection.

Our basic hypothesis was that inspections performed by Rospotrebnadzor required certain resources (material costs and time). Material costs are financial resources spent on labor (salaries paid to workers who perform control and surveillance activities) and costs spent on an inspection itself (documentary and laboratory support). Resources spent on each inspection are taken from the total resource fund allocated for a given year. When developing planning algorithms, it is advisable to ensure that resources are spent evenly (meaning that financial loads are also even) in real time. We should note that time resources are given in actual values; therefore, it is necessary to correlate them with a real time scale for planning inspections within a calendar year. It seems advisable to introduce two time axes: a continuous one showing actual labor costs over time and a real calendar. They should be interrelated with a transformation operator. In this case, several economic entities can be included into a schedule. This transformation is also necessary due to certain requirements fixed in regulatory documents. These requirements concern duration of an inspection, which is usually measured in real time.

Within the suggested approaches, we considered some rules for classifying economic entities, their activities and production facilities; rules for transition from a risk category to periodicity of inspections; rules for regulating parameters of an inspection; rules for using facilities available to Rospotrebnadzor's territorial divisions. As a result, we formulated a conceptual and mathematical basis for describing the analyzed processes. To avoid overloading the text with multiple details, we provide only the basic mathematical relationships used in the suggested algorithms.

The following formula (1) determines the total fund of working time allocated for control and surveillance activities within scheduled inspections at the beginning of a given year:

$$H_0 = \delta \cdot N \cdot (h_f \cdot Y_f + h_{nf} \cdot Y_{nf}), \qquad (1)$$

where H_0 is the total fund of working time allocated for scheduled inspections at the beginning of a year, person-hours;

δ is a share of working time spent by Rospotrebnadzor personnel on scheduled inspections;

N is a number of Rospotrebnadzor personnel who take part in control and surveillance activities;

h_f is a number of hours in a full workday;

Y_f is a number of full workdays in a calendar year (minus vacation);

h_{nf} is a number of hours in a shortened workday (for example, a workday before a public holiday);

Y_{nf} is a number of shortened workdays in a calendar year.

Real time T and the time variable t, which means time spent on scheduled inspections, are bound with the following transformation:

$$T = \frac{365 \cdot 24}{\delta(h_f \cdot Y_f + h_{nf} \cdot Y_{nf})} t, \quad (2)$$

where t is the variable used to express working hours spent by personnel on scheduled inspections; T is the real time variable.

A baseline version of the function that expresses labor costs spent on an inspection involves multiplicative influence exerted by various factors on duration of an inspection:

$$h_{jl} = h_{jl\max} f(r_{jl}) \cdot f(v, K_{jl}) \cdot f(p_{jvl}), \quad (3)$$

where h_{jl} are labor costs spent on an inspection performed at the l-th object belonging to the j-th economic entity, person-hours;

$h_{jl\max}$ are the maximum possible labor costs spent on the inspection performed at the l-th object belonging to the j-th economic entity at $f(r_{jl}) \cdot f(v, K_{jl}) \cdot f(p_{jvl})$ =1, person-hours;

$f(r_{jl})$ is the continuous function of the availability factor of the l-th object belonging to the j-th economic entity;

$f(v, K_{jl})$ is the discrete function of an economic activity and a hazard class of a given object with its values varying from 0 to 1;

$f(p_{jvl})$ is the continuous function of the frequency of detected violations as per the v-th economic activity with its values varying from 0 to 11.

The following formula shows the relationship between Rospotrebnadzor's resources (the left part) with labor costs that are necessary to perform inspections (the right part):

$$Nt = \sum_j h_j(t), \quad (4)$$

where N is a number of Rospotrebnadzor personnel who are involved in control and surveillance activities;

$h_j(t)$ are labor costs on the inspection at the j-th economic entity that have been spent by the moment of time t during the inspection at the j-th economic entity, person-hours.

Labor costs spent on the inspection at the j-th economic entity are determined by a number of inspected objects and labor costs spent on checking each of them:

$$h_j = \sum_{l=1}^{L} a_{jl} h_{jl}, \quad (5)$$

where h_j are labor costs spent on the inspection at j-th economic entity, person-hours;

L is a number of objects belonging to the inspected economic entity, which should be checked;

a_{jl} are weighing factors (from 0 to 1).

We can take $a_{jl} = 1$ for the principal inspected object included into an inspection schedule. As for the other objects, we take $a_{jl}(v) < 1$ depending on an activity. Therefore, this coefficient taken for the principal inspected object covers labor costs both on drawing up relevant documents regarding an inspection at an economic entity (making orders and experts' inquiries; sending notifications to economic entities; issuing inspection reports, orders, statements, records about an administrative offence etc) and on time spent at this object. The coefficients $a_{jl}(v) < 1$ for the remaining inspected objects cover additional labor costs that occur during an inspection at these objects including those performed at the principal one (the main production grounds) and at the others (beyond them).

At present, some clues for determining labor costs can be found in the methodical guidelines "Sample standards for activities performed by organizations and institutions of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing in situations when their budgeting is to be result-oriented". These guidelines were approved by the Rospotrebnadzor's Order issued on October 10, 2008

No. 368[3]. Besides, there are standard calculated labor costs on accomplishing scheduled inspections at economic entities and their objects; they have been established based on regional practices. These documents do not provide any information on a hazard class of activities performed by inspected economic entities and all their production facilities (objects). Given that, all the aforementioned standards are taken as typical for a certain economic entity that falls within an average risk category (the 3rd hazard class as per its economic activity). Besides, the available data were extrapolated when used as reference points as per economic activities and hazard classes. The coefficients a_{jl} were obtained for all the first (principal) objects located at each address by using a relationship between an additional time spent at another address where actual activities were being performed and the overall labor costs spent at checking the first (principal) object located at the main address. All the labor costs on drawing up documentation were also assigned to this main address.

When identifying ranges within which model parameters varied and examining sensitivity of model solutions to changes in these parameters, we spotted out the most sensitive ones. They were a coefficient per frequency of inspections in case violations are absent and extrapolated values of the labor costs function.

The planning algorithms are certain rules for creating a schedule of inspections that are to be accomplished at economic entities and their production facilities and that focus on economic activities performed there within the rick-based model. We suggest three planning algorithms: a basic, alternative, and a combined one. Forecasting scenarios include variants with realistic, minimal, and maximum values of the model parameters.

The basic planning algorithm corresponds to the existing legislation. It is based on an assumption that an inspection should cover an economic entity with all its objects where an economic activity that should be checked is being performed. The algorithm contains the following stages:

1. The register of the operating economic entities and their activities is analyzed with the aim to spot out juridical persons and private entrepreneurs that are to be inspected within the planned period of time according to requirements fixed in the valid regulatory documents;

2. A structured list of economic entities and their activities is created. These economic entities and their activities are selected from the overall list of those that are subject to surveillance within the planned period according to levels of risks they may cause. Bearing in mind that certain economic activities have great hygienic significance, the structured list should primarily include the economic activities that are enlisted in the RF Government Order No. 944 issued on November 23, 2009[4];

3. The first economic entity in the list is included into the inspection schedule with all its objects and economic activities that should be checked; all the necessary labor costs on the inspection are calculated as per the relationship (3);

4. The next step is to determine a number of experts to be involved in an inspection performed at a certain economic entity;

5. Then, we calculate an actual time spent on an inspection, or t (from the formula 4), and calendar time T when an inspection at a given economic entity is complete (2).We should note that the maximum time of inspection completion should be inserted in schedules according to the legislation. This provides flexibility of control and surveillance activities;

[3] Ob utverzhdenii metodicheskikh rekomendatsii «Primernye normativy deyatel'nosti organov i organizatsii federal'noi sluzhby po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka v usloviyakh byudzhetirovaniya, orientirovannogo na rezul'tat»: Prikaz Rospotrebnadzora ot 10.10.2008 № 368 [On Approval of the methodical guidelines "Sample standards for activities performed by organizations and institutions of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing in situations when their budgeting is to be result-oriented": The Rospotrebnadzor's Order issued on October 10, 2008 No. 368]. *GARANT: information and legal support*. Available at: https://base.garant.ru/4187404/ (March 01, 2022) (in Russian).

[4] Ob utverzhdenii perechnya vidov deyatel'nosti v sfere zdravookhraneniya, sfere obrazovaniya, sotsial'noi sfere, v oblasti proizvodstva, ispol'zovaniya i obrashcheniya dragotsennykh metallov i dragotsennykh kamnei, osushchestvlyaemykh yuridicheskimi litsami i individual'nymi predprinimatelyami, v otnoshenii kotorykh planovye proverki provodyatsya s ustanovlennoi periodichnost'yu: postanovlenie Pravitel'stva RF № 944 ot 23.11.2009 [On Approval of the list of economic activities in public healthcare, education, social sphere, production, use and distribution of precious stones and precious metals, which are performed by juridical persons and private entrepreneurs who are subject to scheduled inspections performed according to the established periodicity: The RF Government Order No. 944 issued on November 23, 2009]. *GARANT: information and legal support*. Available at: https://base.garant.ru/12171128/ (March 01, 2022) (in Russian).

6. In case there are available experts who are not involved in any inspection, another economic entity is included into the schedule with the same inspection date. The step continues until there are no more available experts;

7. In case there are not enough available experts to check an economic entity that is the next in the schedule, this entity is given a priority and will be included in the schedule just as a number of available experts is enough to inspect it. The first economic entity in the list for which a required number of experts is available at the present day is the first to be included into the schedule;

8. Experts become available just as an inspection is near its completion (over a time calculated as per the algorithm and not that stated in the schedule according to maximum periods) and the next entity is included into the schedule. The priority is given to economic entities from the priority lists.

The alternative algorithm is based not on analyzing the register of the operating economic entities but on making out a list of their production facilities. It involves inspecting only those objects that are subject to surveillance according to the existing legislation:

1. The register is analyzed with the aim to spot out objects that are subject to surveillance in accordance with the requirements fixed in the valid regulatory documents;

2. A structured list of objects is created where these objects are ranked as per their relevant risks. The priority is given to objects with activities enlisted in the RF Government Order No. 944 issued on November 23, 2009[4];

3. An economic entity that owns the object included as No. 1 in the list is the first to be included into the schedule. Only objects included into the scheduled at the first stage are to be inspected and all the necessary labor costs are calculated in accordance with the relationship (3).

The stages 4–8 are similar to those included into the basic algorithm.

The third algorithm is based on a combined approach. The first two stages in the combined algorithm are similar to those in the basic one. However, only those objects that are included into the list created according to the alternative algorithm are to be inspected and all the labor costs are calculated at the third stage only for inspections performed at these objects. The remaining stages are similar to those included into the basic algorithm.

We selected three criteria to compare these algorithms: coverage of a number of subjects that are to be inspected; coverage of a number of objects that are to be inspected; coverage by the total risk. All these criteria have values form 0 to 1. Coverage of a number of subjects that are to be inspected is calculated as a ratio of a number of subjects included into the schedule to the total number of subjects that are to be inspected within a given calendar year. Coverage of a number of objects that are to be inspected is calculated as a ratio of a number of objects included into the schedule to the total number of objects that are to be inspected within a given calendar year. Coverage by the total risk is calculated as a ratio of a potential health risk caused by economic activities of subjects included into the schedule to a potential health risk caused by economic activities of all the subjects that are to be inspected.

Realistic forecasting scenarios involve setting baseline values of all the coefficients determined at the stage when the model parameters are identified. In forecasting scenarios with the maximum values of parameters, we set the coefficient a_{jl} for the first, second, and next objects at each address at a value being by 1.5 times higher than in the realistic scenario. In a forecasting scenario with the minimum values, we set the coefficient a_{jl} for the first, second and the next objects at each address at a value being by 1.5 times lower than in the realistic scenario. Considering variability of the parameter a_{jl} seems important since the suggested alternative and combined approaches to planning are based on using hazard classes of objects.

Therefore, we considered nine different scenarios for drawing up an inspection schedule: minimum basic, realistic basic and maximum basic; minimum alternative, realistic alternative and maximum alternative; minimum combined, realistic combined and maximum combined. The calculation results are tables with dates of scheduled inspections and necessary labor costs on each inspection.

Results. The suggested approaches were tested using data on a model RF region. The total number of experts involved in control and surveillance activities equaled 272. A parameter showing a share of working time spent by Rospotrebnadzor experts on scheduled inspections was $\delta = 0.32$. In 2019, a number of full workdays amounted to 241 and there were six workdays shortened by 1 hour. Therefore, according to the formula (1), the total working time fund allocated for control and surveillance activities amounted to:

$$H_0 = 0.32\cdot272\cdot(241\cdot8 + 6\cdot7) = = 171{,}468.8 \text{ person – hours} \quad (6)$$

The register of the economic entities, their activities and production facilities in the selected region contains data on 17,049 types of economic activities performed by economic entities; 35,301 production facilities and other objects. Out of them, 1359 belong to the extremely high risk category; 3868, the high risk category; 6871, the significant risk category; 10,031, the average risk category; 9135, the moderate risk category; and 3767, the low risk category. The total health risk equals 1.346 as per the total number of objects; objects belonging to the 1st category (with extremely high risk) account for 83.9 % in this total risk and objects from the 2nd category (high risk) account for another 11.1 % in it.

According to the rules that stipulate transition from a risk category to periodicity of inspections, we set inspection periodicity coefficients for each activity and each production facility (object). Lists of subjects and objects that were to be inspected within a given calendar year were created for all three algorithms (stages 1–2 in them). It was done based on the periodicity coefficients using the random variable generator that conformed to uniformed distribution.

A list created within the basic algorithm included 4205 economic entities, 4710 economic activities performed by them, and 9966 production facilities (objects), or 28.2 % of all the objects in the register. One thousand two hundred and eleven of them belonged to the 1st category (89.1 %) and 1901 objects were from the 2nd category (49.1 %). The total health risk caused by all the objects included in the list amounted to 1.149 thus accounting for 85.3 % of the total health risks as per the overall number of objects included in the register. Labor costs necessary to inspect all the objects belonging to economic entities included in the schedule amounted to 374,684.1 person-hours within the realistic basic scenario; 401,091.7 person-hours, within the maximum basic scenario; and 357,079.1 person-hours, within the minimum realistic scenario. We can see that the resources allocated by Rospotrebnadzor territorial organizations in the model regions are not sufficient within any basic scenario and cannot cover all the production facilities (the formula (6)) that are to be inspected.

We provide a fragment of a table that contains results produced by calculating necessary labor costs according to the basic algorithm for each economic entity ranked as per potential health risks within three possible scenarios, realistic, maximum, and minimum one (stage 3 in the algorithm) (Table 1). At a first approximation, a number of experts involved in inspecting an economic entity N is equal to four in any algorithm (stage 4). The calculation results show that in case a number of objects to be inspected is great, labor costs can be much bigger even when risk levels are similar and economic entities have the same hazard class.

Table 2 provides an example calculation of a real time spent on an inspection, t (from the formula (4)), and a calendar time T when an inspection of an economic entity is complete. The calculations are made within the basic realistic scenario (stages from 5 to 8 in the algorithm).

We can clearly see that the legislation-based date when an inspection should be completed is much earlier than the date of an actual completion that is calculated as per necessary labor costs. It is especially true for those entities that are in the beginning of the list with labor costs being typically higher for them. Obviously, actual inspections accomplished at economic entities that belong to extremely high and high risk categories and have many production facilities (objects) where they perform their activity will require more experts if we wish to complete them in due time fixed in the existing legislation.

As a result, the realistic basic scenario predicts that 1068 economic entities will be covered by inspections during a calendar year (25.4 % of the necessary quantity); 4877 production facilities (objects) or 48.9 % of all the objects that should be inspected; coverage by risk amounts to 1.143 (99.5 % of the total risk caused by economic activities of all the economic entities that should be inspected). Coverage of the objects from the 1st and 2nd category amounts to 100 % (1211 objects) and 86.6 % (1647 objects) accordingly. The maximum basic scenario predicts that inspections will be accomplished at 856 economic entities during

Table 1

Calculation of necessary labor costs as per the basic algorithm for each economic entity (a fragment)

Entity No.	Total risk	Labor costs within the realistic scenario, person-hours	Labor costs within the maximum scenario, person-hours	Labor costs within the minimal scenario, person-hours	A number of objects
1	2.09E-01	922.5	1311.3	663.3	28
2	1.14E-01	548.1	749.7	413.7	15
3	1.89E-01	173.7	188.1	164.1	4
4	7.60E-02	323.1	382.5	303.9	12
5	6.99E-02	349.2	356.4	344.4	5
6	4.47E-02	231.3	274.5	202.5	27
7	3.51E-02	188.1	209.7	173.7	9
8	2.19E-02	375.3	490.5	298.5	13
9	2.28E-02	303.3	382.5	250.5	10
10	1.63E-02	260.1	317.7	221.7	7
11	1.55E-02	173.7	188.1	164.1	3
12	1.31E-02	144.9	144.9	144.9	2
13	2.65E-02	231.3	274.5	202.5	5
14	2.30E-02	620.1	857.7	469.2	48
15	1.03E-02	349.2	356.4	344.4	2
16	9.12E-03	173.7	188.1	164.1	2
17	1.16E-02	1547.1	2187.9	1119.9	115
18	9.80E-03	385.2	410.4	368.4	23
19	6.50E-03	349.2	356.4	344.4	2
20	5.32E-03	144.9	144.9	144.9	1

Table 2

Calculation a real time spent on an inspection, *t* (from the formula (4)), and a calendar time *T* when an inspection of an economic entity is complete within the basic realistic scenario (a fragment)

Entity No.	*t*, hours	*T*, hours	The date when an inspection started	The date when an inspection was completed	The date of an actual completion calculated as per labor costs
1	230.63	3204.75	Jan 01, 2019	Jan 21, 2019	May 14, 2019
2	137.03	1904.09	Jan 01, 2019	Jan 21, 2019	Mar 21, 2019
3	43.43	603.43	Jan 01, 2019	Jan 21, 2019	Jan 26, 2019
4	80.78	1122.44	Jan 01, 2019	Jan 21, 2019	Feb 16, 2019
5	87.30	1213.12	Jan 01, 2019	Jan 21, 2019	Feb 20, 2019
6	57.83	803.53	Jan 01, 2019	Jan 21, 2019	Feb 03, 2019
7	47.03	653.46	Jan 01, 2019	Jan 21, 2019	Jan 28, 2019
8	93.83	1303.79	Jan 01, 2019	Jan 21, 2019	Feb 24, 2019
9	75.83	1053.66	Jan 01, 2019	Jan 21, 2019	Feb 13, 2019
10	65.03	903.58	Jan 01, 2019	Jan 21, 2019	Feb 07, 2019
…	…	…	…	…	…
101	60.45	840.01	Feb 18, 2019	Mar 10, 2019	Mar 25, 2019
102	36.56	508.07	Feb 18, 2019	Mar 10, 2019	Mar 11, 2019
103	55.74	774.52	Feb 20, 2019	Mar 12, 2019	Mar 24, 2019
104	26.49	368.07	Feb 20, 2019	Mar 12, 2019	Mar 07, 2019
105	26.49	368.07	Feb 20, 2019	Mar 12, 2019	Mar 07, 2019
106	26.49	368.07	Feb 20, 2019	Mar 12, 2019	Mar 07, 2019
107	146.74	2039.06	Feb 20, 2019	Mar 12, 2019	May 16, 2019
108	23.89	331.94	Feb 21, 2019	Mar 13, 2019	Mar 07, 2019
109	46.31	643.56	Feb 22, 2019	Mar 14, 2019	Mar 21, 2019
110	33.53	465.86	Feb 24, 2019	Mar 16, 2019	Mar 15, 2019

a calendar year (20.4 % of the necessary quantity); 3911 production facilities (objects) or 39.2 % of all the objects that should be inspected; coverage by risk amounts to 1.141 (99.3 % of the total risk caused by economic activities of all the economic entities that should be inspected). However, within this scenario, only 76.1 % of the objects from the 1st and 2nd category will be inspected. The minimum basic scenario predicts inspections to be accomplished at 1254 economic entities during a calendar year (29.8 % of the necessary quantity); 5551 production facilities (objects) will be inspected (55.7 % of the total number of objects that should be inspected); 1.144 risk will be covered (99.6 % of the total risk caused by economic activities of economic entities that should be inspected). Within this scenario, inspections cover 99.9 % of all the objects from the 1st and 2nd categories.

The alternative algorithm allowed creating a list with 4882 economic entities and 10,764 production facilities (objects) (30.5 % of all the objects in the register). One thousand one hundred and sixteen of them belonged to the 1st category (82.1 %) and 1839 belonged to the 2nd category (47.5 %). The total health risk caused by all the objects in the list amounted to 1.157, which accounted for 85.3 % of the total number of objects in the regional register. According to the realistic alternative scenario, labor costs that were necessary to inspect all objects belonging to economic entities included in the list amounted to 388,655.5 person-hours; the minimum alternative scenario, 401,091.7 person-hours; the maximum alternative scenario, 410,862.7 person-hours. Obviously, resources allocated by Rospotrebnadzor on scheduled inspections are not sufficient to cover all the production facilities (objects) that should be inspected within any alternative scenario (the formula (6)).

As a result, the alternative realistic scenario predicts that 1027 economic entities will be covered by inspections during a calendar year (21 % of the necessary quantity); 5035 production facilities (objects) or 47.2 % of all the objects that should be inspected; 1.148 risk (99.2 % of the total risk caused by economic activities of all the economic entities that should be inspected). Coverage of the objects from the 1st and 2nd category amounts to 100 % (1116 objects) and 93.2 % (17,157 objects) accordingly. The maximum alternative scenario predicts that inspections will be accomplished at 880 economic entities during a calendar year (18 % of the necessary quantity); 4061 production facilities (objects), which accounts for 38 % of all the objects that should be inspected; 1.146 risk (99.1 % of the total risk caused by economic activities of all the economic entities that should be inspected. However, within this scenario, only 82.5 % of the objects from the 1st and 2nd category will be inspected. The minimum alternative scenario predicts inspections to be accomplished at 1151 economic entities during a calendar year (23.6 % of the necessary quantity); 5260 production facilities (objects) will be inspected (49.3 % of the total number of objects that should be inspected); 1.149 risk will be covered (99.4 % of the total risk caused by economic activities of economic entities that should be inspected). Within this scenario, inspections cover 97.4 % of all the objects from the 1st and 2nd categories.

The combined algorithm assumes that if an economic entity that should be inspected in this calendar year has only one production facility, this facility should be inspected regardless of being included in the list created within the alternative algorithm or not. According to the combined algorithm, the list included 3961 economic entities and 7134 production facilities (objects) (20.2 % of all the objects in the register), 1033 of them belonging to the 1st category (76.0 %) and 1205 to the 2nd category (31.1 %). The total health risk caused by all the objects in the list amounts to 1.112, which accounts for 82.4 % of the total health risk caused by all the objects in the register. According to the realistic combined scenario, labor costs that were necessary to inspect all objects belonging to economic entities included in the list amounted to 306,550 person-hours; the maximum combined scenario, 322,266.3 person-hours; the minimum combined scenario, 296,105.5 person-hours. We can again clearly see that resources allocated by Rospotrebnadzor on scheduled inspections in the model regions are again insufficient to cover all the listed objects in all three scenarios (the formula (6)). Still, these necessary labor costs calculated according to the combined algorithms are approximately by 25 % lower than the costs calculated by using the basic or alternative algorithm.

As a result, the realistic combined scenario predicts 1337 economic entities (33.8 % of the necessary quantity) and 3950 production facilities (objects (55.4 % of all the objects that should be inspected) to be covered with inspections during a calendar year. A covered risk amounts to 1.108 (99.7 % of the total risk caused by all economic entities that should be inspected). The maximum combined scenario predicts inspections to be accomplished at 1145 economic entities (28.9 % of the necessary quantity) during a calendar year. Three thousand three hundred and twelve objects will be inspected (46.4 % of the total number of objects that should be checked) and 1.107 risk will be covered (99.6 % of the total risk caused by all economic entities that should be inspected). The minimum combined scenario predicts that inspections will cover 1474 economic entities (37.2 % of the necessary quantity); 4125 production facilities (objects) (57.8 % of all the objects that should be inspected); 1.109 risk (99.7 % of the total risk caused by all the economic entities that should be inspected). Inspections will cover 83.0 % of the objects from the 1st and 2nd categories within the maximum combined scenario. This coverage amounts to 99.9 % within two other maximum scenarios, basic and alternative one.

Therefore, the alternative algorithm produced coverage rates that were quite similar to those calculated with the basic algorithm. The combined algorithm produces greater coverage rates since not every object is checked when an economic entity is being inspected. Only the most hazardous objects are covered by an inspection thereby reducing labor costs spent on it.

Discussion. We described parameters of interactions between Rospotrebnadzor and economic entities within control and surveillance activities. This allowed us to spot out major characteristics that give an opportunity to describe how Rospotrebnadzor resources are spent in terms of labor costs. One of our primary hypotheses is that the total working time fund allocated for control and surveillance activities is spent evenly. When an inspection schedule is created, it is advisable to distribute loads evenly so that personnel work in ergonomic conditions without any unnecessary deadline pressures.

The relationships, which we introduced with the mathematical statement of the task, allowed us to consider a history of violations (integrity and law abidance of an economic entity) during a given period; parameters related to availability of objects for an inspection including both regional peculiarities (a distance between objects, quality of a road network) and "complexity" of checking a specific object. Differentiation of production facilities (objects) that belong to an economic entity gives grounds for planning volumes and contents of surveillance activities.

We identified the model parameters at a first approximation. These parameters can be used to estimate and substantiate the necessity and sufficiency of resources involved in performing control and surveillance activities. We determined which model parameters had the greatest influence on the solution, that is, the most sensitive parameters that should be regulated with special care if we want to make control and surveillance activities performed by Rospotrebnadzor more effective.

The results produced by testing the suggested algorithms prove their relevance and efficiency. However, conclusions on the suggested algorithms being effective require more profound examination of the results. This might include examining results produced by a more complicated model, for example, a model that allows for territorial distribution of Rospotrebnadzor organizations within a given region. Besides, we should additionally discuss whether it is advisable to check all the production facilities of an economic entity (within the existing legislation) bearing in mind that a hazard class of some objects belonging to this entity may be lower than a hazard class of specific economic activities performed by it.

Conclusion. This study has provided further development of theoretical and applied aspects of the risk-based model for control and surveillance activities performed by Rospotrebnadzor. We have also developed a scientific basis for describing interactions between Rospotrebnadzor and economic entities. Among other things, we have suggested new approaches to improving planning of Rospotrebnadzor activities involved in inspecting economic entities and their production facilities.

We have produced new statements (conceptual and mathematical) that give an opportunity to provide a formal description of an inspection process within the risk-based model. We have determined certain parameters of the described processes together with identifying the major parameters and indicators that should be considered within the suggested model. We have created three planning algorithms, which can be considered rules for drawing up an inspection schedule. This schedule comprises inspections of economic activities performed by economic entities and productions facilities used by them in the process within the risk-based model. We have selected three criteria to compare the algorithms: coverage of a number of subjects that are to be inspected; coverage of a number of objects that are to be inspected; coverage by the total risk.

The suggested approaches have been tested at a regional level. The testing results indicate that the combined algorithm produces greater coverage rates. The developed approaches give an opportunity to create planning algorithms with preset (predicted) values of parameters and to assess whether the algorithms are effective using the suggested comparison criteria. Ultimately, this will allow more effective distribution and use of Rospotrebnadzor resources allocated for scheduled inspections.

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