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Research Article

Management of Urban Population Health Risk caused by Motor Vehicle Pollution

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ABSTRACT:
The paper presents the results of scientific research in the field of urban pollution caused by operation of vehicles. The types and place of automotive pollution in the overall negative impact of the technosphere on a human body and habitat are considered. Theoretical approaches and models for calculating the risk to the health of urban population are described. The main provisions of the methodology for managing the health risk of the population are presented.

Keywords: urban environment, motor vehicle pollution, public health risk, evaluation, calculation models, management.

1. INTRODUCTION

Provision of public health in modern urban conditions is an urgent task of the scientific community. Upon that, the urban population health risk is one of the main evaluation characteristics of the technosphere state in the context of the global social and natural system "human - environment". According to scientific concepts, risk is a quantitative measure of danger, which determines the probability of a negative event and the consequences of damage [1, p. 10]. The relationship between the categories "danger" (D) and "risk" (R) can be expressed by the logical formula

D - M - E - R,

Where M is a manifestation of danger; E - negative effect (effect); R - risk (evaluated).

Currently, the population of many cities in Russia experiences a significant impact of adverse man-made factors, one of which is urban vehicles. Thus, according to statistical data [2, p. 42], the contribution of cars and buses to urban pollution is 68-90% (Table. 1).

Table 1: Contribution of automotive pollution to atmospheric pollution in Russian cities

Item No.	City name	Proportion of road pollution, %
1	Armavir	90
2	Sochi	85
3	Tyumen	84
4	Tambov	81
5	Voronezh	78
6	Krasnodar	74
7	Makhachkala	72
8	Rostov-on-Don	68

The average share of motor vehicles in total emissions of pollutants into the atmosphere in the territory of Russia is 45% of all sources. [3, p. 14]. According to the statistical data of the analytical laboratory SIC PROMEX LLC, in 2015 in the large industrial city of Shakhty (Rostov region), road transport produced about 70% of emissions from the total amount of atmospheric pollution. The following harmful compounds are identified in quantitative terms: carbon and nitrogen oxides, hydrocarbons, soot, carcinogens, lead compounds. Among the main pollutants entering the urban atmosphere with exhaust gases of cars are formaldehyde, lead, benzapyrene, volatile hydrocarbons. The content of the strongest carcinogen, benzapyrene, in the atmosphere of 17 cities of the Rostov Region exceeds the maximum permissible standards [4, p. 112]. A detailed study by many researchers of the impact of automotive pollution on the environment made it possible to establish that there is a stable causal relationship between the presence of these pollutants in the atmosphere and the health status of urban residents.

If to follow the fundamental provisions of mathematics, environmental security represents a class of "large" systems. The system of this scientific category is characterized by the possibility of carrying out the following logical and mathematical operations:

- Classification of the system by qualitative and quantitative characteristics;
- Integrated system analysis with breakdown to elements in order to study the objects forming the system, as well as the mechanisms of their interaction, properties, and relationships;
- Synthesis of the components of the system under study into a single structure.

The respresented results cause systematic research of all motor vehicle pollution sources for an urban environment within the limits of the analysis of their negative influence on health of the population and the subsequent development of the specified risk management technique.

At the present stage of science development, the problem under consideration has not been studied systematically. This is convincingly evidenced by the absence of an integral, scientifically grounded methodology for assessing road transport risk [1, p. 39; 5, p. 5-6]. At the same time, the need to develop such a document grows, because the number of cars and buses in the roads of Russia permanently increases. At the same time, the intensity of vehicle operation has significantly increased. All these factors have caused an increase in the technogenic burden on the habitat and morbidity of the urban population.

The current situation in the field of research of road transport pollution and the risk to human health from their impact led the authors of this paper to the necessity of presenting the results of their scientific work on this issue.

2. RESEARCH METHODOLOGY FOR EVALUATION OF NEGATIVE IMPACT OF MOTOR TRANSPORT ON HEALTH OF URBAN POPULATION

The authors hold the scientific position according to which a complex of studies must necessarily include both theoretical and experimental research. Consequently, the program of research work should contain logically related steps, including formation of fundamental principles, the choice of methods and means of observation, development of a hypothesis, solution of issues on modeling, creation of an algorithm for processing and generalizing the results. The implementation of this concept allows us to test objectively the working hypothesis in practice. The essence of the hypothesis is that the implementation of a complex of observations and analysis of materials based on a method justified by experimental and theoretical research using system analysis and synthesis provides a reliable estimate of the risk to health of urban population from motor vehicle pollution and subsequent effective risk management.

The following provisions are put forward as basic methodological principles:

- A systematic approach to the construction of observation networks, to analysis of objects, factors and relationships;
- The scientific adequacy principle (correspondence of the selected methods to the object under study);
- The principle of validity for the application of system information analysis;
- Rational combination of research methods;
- The principle of formalization of interpretation procedures and the use of an adequate mathematical apparatus;
- The principle of a compromise between the expected accuracy and the complexity of implementing the methodology used;
- The principle of natural specificity of the object being under investigation;

- The principle of counterintuitive behavior of complex systems.

The application of the first principle follows from the definition of environmental safety as a system and, accordingly, the need to study all elements of a given structure, their interrelations, forms and directions of interaction. The results of this study provide complete and objective information.

The second principle indicates that the methods are selected based on the analysis of information about the structure of the object under study, its parameters, properties, relationships, and possible dynamic trends. The method of research should correspond to the level of organization of the structure being studied; therefore, it is necessary to apply rational sets of methods to develop an assessment for the "large" systems state dynamics. The situation in the practice of obtaining information about an object under investigation usually develops in such a way that the possibilities of simple analytical and computer tools are not enough to assess the man-made impacts on the environment. Therefore, the achievement of high quality assessment is proposed to provide through an integrated system analysis (ISA) of an object. The essence of the integrated system analysis consists in that it is necessary to perform a complex analysis by a certain set of methods. As practice shows, reliability of the evaluation results increases if the so-called process analysis is applied together with system analysis.

Complexation of methods ensures the achievement of high efficiency in obtaining primary information. It follows from the analysis of practical materials that the application of complexation makes it possible to increase the reliability of the obtained data results by at least 10-15% in comparison with the study by the most sophisticated private methods using some essential basis, for example, a physical field or a mathematical principle [6, p. 30].

The use of the fifth methodological principle in the practice of risk research makes it possible to more clearly formulate tasks and form an algorithm of work; and also to speed up multiply the processing of primary results.

Achieving a compromise between risk assessment indicators and the volume of implementation of analytical procedures presents a difficult scientific, technical and economic problem. The use of complex and high-precision methods in the calculation practice increases the labor and financial costs significantly. At the same time, simplification of the research technology leads to the so-called "scientific uncertainty" of the results. In this regard, specialists have to find a reasonable balance within the formula of "price/quality" with the obligatory consideration of the requirements which are indicated in the research task.

The principle of natural specificity requires the performers of scientific work to take into account the features of the investigated object and the constituent elements, as well as the laws of its development, the necessary limitations and limits of evolution.

Accounting for the counterintuitive principle is justified by the indisputable fact that all complex systems (including environmental ones) do not behave in practice as intuition dictates, that is, the process proceeds counterintuitively [6, p. 32; 7, p. 6787; 8, p. 1193; 9, p. 6 ; 10, p. 60]. This vector of behavior is determined by the objective complexity of the urban technosphere and some subjectivity of scientific knowledge on this issue.

The assessment of the automotive pollution impact should be based solely on criteria that reflect the direct impact of harmful substances on the health of the urban population. Indicators, for example, the discomfort states change risk, can be used as an additional criterion in the risk analysis carried out with a view to prioritizing problems, including those which characterize the life of the population. Assessment of the human health risk is a procedure for determining the likelihood of development and the level of negative consequences for the population that are caused by the impact of an urban technosphere factors complex.

A common element in the analysis of road transport risk, evaluation of its parameters and risk management is that the listed above procedures are three stages of a logically connected decision-making process. This commonality is objectively conditioned by an objective function, namely the definition of priorities for actions aimed at reducing the health risk to a possible minimum ("acceptable" risk). To achieve this goal, it is necessary to perform the following works: determine its sources and factors (analysis stage); to carry out the forecast of their behavior in the long term (space-time estimation of characteristics), and to formulate effective ways to reduce risk (risk management). Here it should be made one point which has an important scientific and methodological significance and indicates that the analysis of the health risk should be viewed as a process of solving multicriteria problems.

The stage of risk assessment should include the following mathematical procedures: calculation of a negative event frequency and its consequences as well as their combination, for public health. Upon that, the "dose-response" analytic function is the main operation, which is a quantitative characteristic of the relationship between the exposure dose of a pollutant release and the cases of diseases of the urban population. The methodology for assessing road transport risk is based on the widely used method of calculated emission inventory [9, p. 7]. The essence of this method is that the sections of the road network that are characterized by the maximum negative impact on the urban environment are initially determined on the basis of a priori information on the characteristics of road transport, its serviceability status, condition and operating modes. Further, a detailed calculation of the emission of pollutants in the studied sections of roads is carried out. Then, a risk is identified that represents an assessment of the consequences for the urban population of pollutant emissions in the normal operation of vehicles, as well as in the event of potential accidents. In the process of implementing the next stage, it is necessary to synthesize the private data to obtain conclusions on the general situation with urban pollution. This logical-mathematical operation will allow specialists to present a general picture of the distribution of negative impacts on the environment and health of the urban population in the context of the overall research strategy. In general, the stage of analysis of the risk to the health of a city dweller can be represented by the scheme presented in

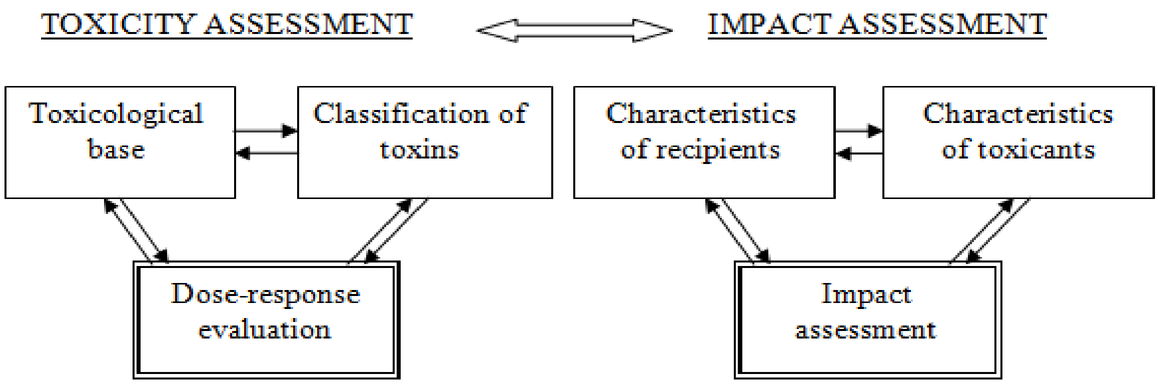

Fig. (1). Algorithm for analyzing the risk to human health from the impact of vehicles.

According to the authors, assessment of the transport impact on human health risk should be made using an analytical complex that includes the following criteria:

- Carcinogenic potential for harmful release, characterizing an individual carcinogenic risk or the degree of increase in the likelihood of developing cancer when inhaled a chemical that has a carcinogenic effect;
- Safe concentration with acute exposure to the substance;
- Reference concentration for chronic inhalation exposure;
- Maximum permissible one-time concentration;
- Maximum daily allowable concentration;
- Indicative safe levels of exposure;
- Indicators of dose-response relationships.

One of the main provisions of the author's methodology, its "cornerstones", is the use in a risk analysis of a set of models, including pollution models, models for the interaction between vehicle emissions and the environment and a human body, mathematical models (dependencies) of the "dose-response" type, etc.

Simulation allows quickly and reliably to assess the situation and perform the necessary calculations with relatively low labor input.

3. RESULTS OF EXPERIMENTAL STUDIES

To test the working hypothesis and approbate of the developed methodological provisions, the authors carried out a series of experimental works in the town of Shakhty in the Rostov region. As stated above, motor transport is one of the main pollutants of the atmosphere in the region, because its territory is crossed by several highways of federal importance.

The program of practical observations of automotive pollutions was formed based on the results of monitoring and analysis of statistical data from the Shakhty Sanitary and Epidemiological Station and Research and Development Center "PROMEX". The method of medical-ecological mapping, taking into account the multifaceted anthropogenic load on nature and human, was used in the development of the observation methodology. The highest value of this method, from the point of view of protecting human health, is the possibility of differentiated presentation of the depth of ecological and hygienic disturbances of the state of objects, long-term forecasting of transformations of negative trends, determining the reliability of the most dangerous "hot" points of negative impact on the environment, and then developing adequate measures to improve the sanitary and hygienic situation. A characteristic feature of medical and ecological zoning is that the expert basis of the method comprised of the territorial features of the cause-effect relationships between the state of health of the urban population and the negative factors affecting it, for example, emissions of motor vehicles.

Ten checkpoints were selected near the highways with the highest traffic located in all areas of the city (tab. 2).

Table 2: A list of the control points for the study of atmospheric air on motorways in the town of Shakhty

Point number	A district of the city	Control point address
1	Centre	Sovietskaya str., 134
2	Centre	Sovietskaya str., 170
3	Centre	Sovietskaya str., 55
4	Centre	Pobedy Revolutsii av., 85
5	Centre	K. Marx av., 110
6th	Microdistrict "Parkovaya"	Parkovaya str. 54
7th	Microdistrict "Sotsgorod"	Chernokozova av., 95
8	Microdistrict "Sotsgorod"	Mayakovsky str., 105
9	Centre	Pobedy Revolutsii av., 130
10	Artyom district	Leninskogo Komsomola av., 32

The assessment of the state of atmosphere was made at each control point, using a set of indicators, which included the following names of pollutants: nitrogen dioxide, benzene, benzapyrene, suspended substances, ethylbenzene, dimethylbenzene, lead compounds, sulfur dioxide, carbon monoxide, formaldehyde, and ethylbenzene.

The authors determined the quantitative characteristics of the pollution by the use of the special calculations, including the amount of emission, depending on the type of engine installed on the same type of motor vehicles (buses, cars, etc.). The results are shown in Table 3.

Table 3: Emissions of pollutants depending on the type of transport and engine type

Type of vehicle	Type of fuel	
	Petrol	Diesel fuel
Buses	4.7	0.2
Trucks	40.5	4.0
Cars	50.4	0.2

Note. The figures indicate the contribution of the type of motor transport (%)

As can be seen from the table, the maximum volume of emissions is made by trucks and cars using petrol as fuel. The results of the analysis given in Table 3 allow us to substantiate the organizational and technical measures for managing the traffic flows in the city and for choosing the mode of passenger transportation. So, for example, you can make a consequential decision on transfer of buses and cars to clean gas fuel. This will significantly reduce the emission of harmful substances into the urban atmosphere.

The priority selection of pollutants within the framework of further analysis was carried out on the basis of identification of the contamination dangers for public health [5, p. 9]. At the same time, data monitoring of the content of substances in the surface air layer, obtained by the employees of the analytical laboratory Research and Development Center "Promex" Ltd. have been also taken into account. As a result of a joint analysis of the analysis materials, the authors compiled a list of priority chemicals for the analysis of urban risks from road pollution. The list of analyzed elements and compounds is presented in Table 4.

Table 4: List of priority chemicals included in the risk analysis

	Substance	MPC, mg / m^3	Hazard Class	Critical organs / systems
1	Phenol	0.003	2	Cardiovascular system, liver, central nervous system
2	Nitrogen dioxide	0.04	2	Respiratory system
3	Formaldehyde	0.01		Respiratory system
4	Carbon monoxide	3	4	Cardiovascular system, central nervous system, blood
5	Sulphur dioxide			Respiratory system
6	Suspended substances	0.5	3	Respiratory system
7	Lead	0.3	1	Respiratory system
8	Chlorine	350	3	Circulatory system, gastrointestinal tract
9	Nitrates	45.0	3	Circulatory system

Emissions of harmful substances into the atmosphere from motor vehicles were determined by the calculation method on the basis of the following characteristics: the traffic intensity and the structure of the transportation flow; motor transport traffic condition in space-time coordinates. At the same time, the average daily traffic intensity was estimated taking into account the daily intensity variation.

Determination of exposure levels from automotive pollution was based on the implementation of a comprehensive study, including the following factors:

- The territorial location of emission sources of pollutants;
- Distribution of the technosphere contamination;
- Calculated average annual, average daily and short-term exposure limits of pollutants at control points of exposure to human body.

When assessing the level of health risks to the urban population affected by vehicle emissions, the following leading indicators were taken into account: the impact from vehicles, traffic intensity; excess of MPC of chemical substances in the atmosphere. The primary assessment of pollution of the urban atmosphere with chemicals at control points was carried out by a standard method - in terms of the multiplicity of excess MPC

$K = Cm / MPC$,

where Cm is the maximum concentration of the estimated pollutant in the surface air. The estimation of atmospheric air pollution level was also carried out using the indicators established by Roshydromet (Federal Service of Russia on Hydrometeorology and Monitoring of the Environment) for comparative assessment of atmospheric air parameters relative to the average level of pollution in the cities of the Russian Federation:

- Standard index (SI) - short-term exposure limit of pollutant for the observation period;
- The highest frequency of MPC exceeding occurrence for the study period, %;
- Complex atmospheric air pollution index (API);

The trend of the atmospheric air pollution level dynamics was calculated by the formula

$Td = (0.2q_5 + 0.1q_4 - 0.1q_2 - 0.2q_1)$,

where q_1, q_2, q_4, q_5 are average concentrations of the pollutant for the first, second, fourth and fifth series of observations

[10, p. 201].

Assessment of surface layers pollution in the urban atmosphere was carried out using the total pollution coefficient in accordance with regulatory documents.

According to the results of surveillance studies, the priority atmospheric pollutants in the town of Shakhty are: nitrogen dioxide - 61.5%; suspended solids - 18%; and benzopyrine - 18%. The greatest excess of MPC is noted for suspended substances (3.27 times), nitrogen dioxide (2.8 times) and benzapyrene (2.4 times). Priority urban areas where the greatest excess of hygienic standards was observed in 2015 were the town center and microdistrict "Sotsgorod". During the study period, there was a pronounced increase in the proportion of the samples under study with an MPC exceeding the content of harmful substances in the ambient air. At the same time, according to the statistical indicators of individual pollutants, it is not possible to assess the complex effect of chemical pollutants on the population health. The atmospheric air pollution index (API) is calculated by 9 ingredients of substances selected at ten points of average daily observations. As a result of the calculation, the API pollution level in the town of Shakhty was estimated at 3.63.

Joint analysis of actual measurement results in the town of Shakhty and scientific publications allowed the main provisions to formulate for the methodology for assessing the risk to the health of the urban population. The risk to human health is assessed as the probability of development and impact of adverse effects on human health. The situation should be considered in the multidimensional space of the technospheric hazard which includes the following variables: spatial coordinates; time (hour, day, etc.); substances - pollutants; sources of harmful emissions; focus of effects on human body systems.

The conceptual model of a hygienic assessment of the urban population health risk from the impact of vehicles presents a detailed algorithm consisting of logically sequential steps in the collection and analysis of information for the formulation of management decisions. The complex of the described solutions is aimed at the realization of the objective function: reducing the impact of automotive pollution on the health of the urban population. The developed model objectively reflects the system of interrelated actions of supervisors, hygienists and managers who must collect and analyze information about motor vehicle pollution, as well as quantitative and qualitative parameters for a human health risk due to the impact of road transport. The model analogue of the real processes in the system "motor transport emissions - human health", as well as a number of other models on which risk analysis relies, was developed taking into account fundamental methodological approaches and is an important element of regional monitoring [6, p. 85; 12, p. 3526; 13, p. 1036; 14, p. 12084; 15, p. 1122; 16, p. 99]. The analysis of the received factual base with the use of the monitoring system makes it possible to assess in real time the situation, to identify problem areas in terms of the pollution impact, and to justify the optimal solutions to reduce the risk.

Based on the results of the assessment, a system for managing the health risks of the urban population from the functioning of vehicles has been constructed. It is important to note that, at the same time, the principle of consistency and uniformity of procedures must be observed, according to which the final phase of the risk assessment must simultaneously be the first link in the risk management procedure. Thus, the health risk management algorithm should include four stages. At the first stage, the risks are compared in order to establish priorities and the degree of danger is determined. The second stage involves determination of the risk acceptability. Risk is compared with a number of socio-economic factors: the benefits of a particular type of activities; losses caused by the use of the activity; availability and opportunities of regulatory measures to reduce the negative impact on the environment and human health. When comparing "risk-free" and "risky" situations, three solutions are possible: the risk is acceptable completely, the risk is acceptable in part, and the risk is completely unacceptable. The third stage is the selection of one of the standard measures that contribute to reducing (eliminating) the risk. At the fourth stage, a regulatory (managerial) decision is formulated.

The proposed health risk management model is shown in the diagram in Figure 2.

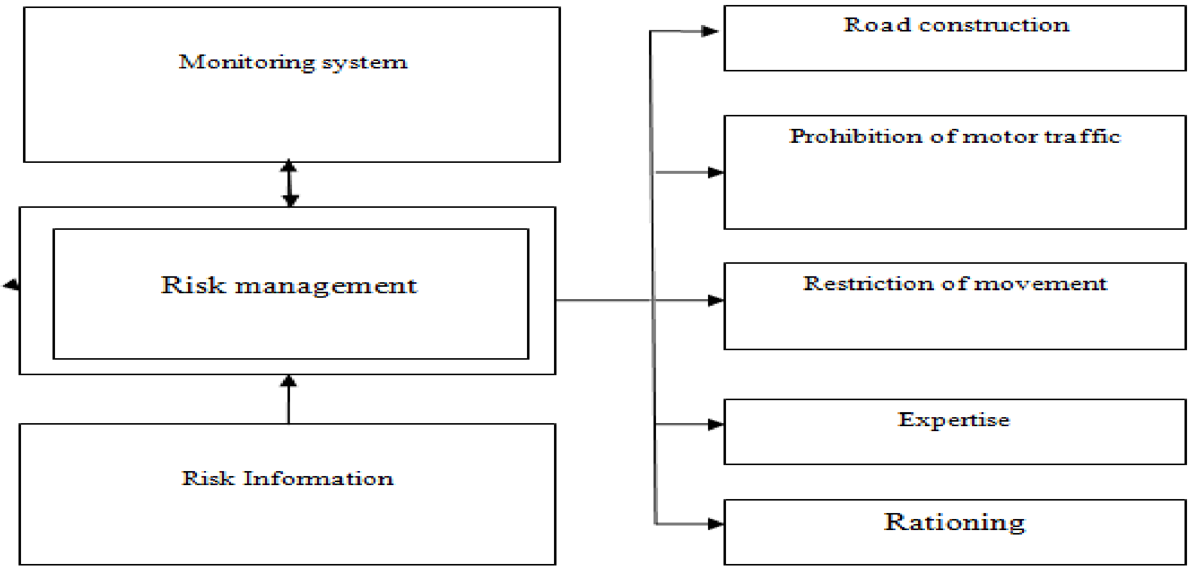

Fig. 2. Model of urban health risk management

The application of the presented model allows an effective evaluation system to develop for the impact of vehicles on the population health and formation on its basis of management decisions in order to reduce the risk.

As practice shows, the successful implementation of the developed method of risk to public health is provided by realization of a set of organizational and technical conditions that reflect the adaptation of methodological provisions to the real situation. In particular, the perspective direction is the introduction of models for hygienic assessment and management of public health risk when performing architectural and planning works.

4. DISCUSSION OF THE RESEARCH RESULTS

This paper presents the main approaches to assessing the health risk for the population of Russian cities due to the impact of road transport pollution. The developed theoretical and methodical positions do not contradict the fundamental theories of mathematics, ecology and technospheric security. A characteristic feature of the proposed methodology is the possibility of optimizing control decisions depending on the current ecological state of the urban environment. The difference of author's recommendations from previous studies of other specialists is the implementation of logically interrelated procedures, including risk analysis and assessment, and management of the urban population health risk on their basis.

The working hypothesis is confirmed in the process of experimental and methodological work using the formulated methodological principles.

5. CONCLUSION

Based on the results of the research, it can be concluded that the use of methods and tools that constitute the author's method for assessing the risks to public health allows improving the level of environmental safety management, including the population health risk from road pollution.

The proposed methodology can be used in all "big" cities, because it is developed on the basis of integrated system analysis and noxology, and the established trends in the system "pollution impact - the risk to human health" are universal.

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CONFLICT OF INTEREST

The authors confirm that the presented data do not contain a conflict of interest.

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