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Analytical hierarchy process as a tool supporting a decision-making for assessment of the risk of transboundary infectious animal disease introduction to the Russian Federation and previously disease-free territories

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SUMMARY

The livestock industry is increasingly taking its place in the economy of the Russian Federation. Its export potential is actively growing. Already, up to 10% of agricultural products are exported to foreign markets. The demand for food steadily increases during crises, which in turn increases the role of the veterinary service, whose tasks include protecting the country's territory from the introduction of infectious diseases of animals from foreign countries; implementation of measures to prevent and eliminate infectious and other diseases in agricultural, domestic, zoo and other animals, fur-bearing animals, birds, fish and bees, as well as the implementation of plans of the regional veterinary service in the field of animal husbandry. The article assesses the validity of the possibilities and use of modern methods of analyzing and predicting the spread of animal morbidity, identifying cause-and-effect relationships and the extent of the spread of particularly dangerous animal diseases. The authors propose to consider the possibility of using the mathematical method of hierarchy analysis as a scientifically sound decision-making support tool when assessing the risk of introducing trans-border infectious animal diseases into previously prosperous territories of the Russian Federation. This approach can be used in the process of choosing the most appropriate alternative from several risk assessment options. The Hierarchy Analysis Method is a mathematical tool for a qualitative systematic approach to solving decision-making problems. This method was developed by the American scientist Thomas Lewis Saati in 1970, since then it has been actively developing and widely used in practice. The hierarchy analysis method can be used not only to compare objects, but also to solve more complex management and forecasting tasks.

Keywords: transboundary infectious animal diseases, disease-free territory, risk assessment, economic damage, epidemic situation, Analytical Hierarchy Process method, decision-making support

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Метод анализа иерархий как инструмент поддержки принятия решений при оценке риска заноса трансграничных инфекционных болезней животных на территорию Российской Федерации и на ранее благополучные территории

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РЕЗЮМЕ

Отрасль животноводства все увереннее занимает свое место в экономике Российской Федерации. Активно растет ее экспортный потенциал. Уже сейчас на внешние рынки экспортируется до 10% производимой продукции сельского хозяйства. Спрос на продовольствие стабильно увеличивается в период кризисов, что, в свою очередь, повышает роль ветеринарной службы, задачами которой является охрана территории страны от заноса заразных болезней животных из иностранных государств, реализация мероприятий по предупреждению и ликвидации инфекционных и иных болезней сельскохозяйственных, домашних, зоопарковых и других животных, пушных зверей, птиц, рыб и пчел и осуществление региональных планов ветеринарного обслуживания животноводства. В статье дается обоснование и оценка возможности использования современных методов для анализа и прогнозирования распространения заболеваемости животных, выявления причинно-следственных связей, масштаба распространения особо опасных болезней животных. Авторами предлагается к рассмотрению возможность применения математического метода анализа иерархий в качестве научно-обоснованного инструмента поддержки принятия решений при оценке риска заноса трансграничных инфекционных болезней животных на ранее благополучные территории Российской Федерации. Данный подход может быть использован в процессе выбора наиболее актуальной альтернативы из нескольких вариантов оценки риска. Метод анализа иерархий – математический инструмент качественного системного подхода к решению проблем принятия решений. Этот метод разработан американским ученым Томасом Льюисом Саати в 1970-х годах, с тех пор он активно развивается и широко используется на практике. Метод анализа иерархий можно применять не только для сравнения объектов, но и для решения более сложных проблем управления и прогнозирования.

Ключевые слова: трансграничные инфекционные болезни животных, благополучная территория, оценка риска, экономический ущерб, эпизоотическая ситуация, метод анализа иерархий, поддержка принятия решений

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INTRODUCTION

The Russian Federation continues to increase the domestic production of animal products, thus contributing to the enhancement of food security of the country, facilitating the availability of food products to the population, provision of raw material for industries [1]. Though still dependent on external economic factors, the livestock sector confidently begins to occupy an important place in the country's economy. Its export potential is actively growing. Up to 10% of agricultural products are already exported to foreign markets. The demand for food is known to steadily increase during crises. The demand for agricultural products is also influenced by demographic factor. By 2030, 765 million new consumers will appear in the world; of these, 340 million will live in Africa, 126 million – in India, 30 million – in China [2]. The government investment policy has produced certain results – modern livestock and poultry facilities for production of pork, milk, poultry meat and eggs have been built. At the same time, the spread of infectious animal diseases, in particular zoonoses, has escalated due to globalization processes. According to the Veterinary Law of the Russian Federation, the tasks in the veterinary field are as follows: to protect the territory of the country from the introduction of contagious animal diseases from foreign countries, to take measures for the prevention and elimination of contagious and other diseases of agricultural, domestic, zoo and other animals, fur-bearing animals, birds, fish and bees, as well as to implement regional plans on the veterinary services to be provided to animal farming sector. A specific feature of Russia is a long land border with the neighbouring countries infected with transboundary animal diseases [3].

Transboundary animal diseases (TADs) are epidemic diseases, which are highly contagious or transmissible and have the potential for rapid transmission; they can easily spread across borders and reach epidemic proportions. The control/management, including eradication, of transboundary animal diseases require cooperation between several countries [4–6]. As defined by the World Organisation for Animal Health, such diseases include African horse sickness, African swine fever (ASF), bluetongue disease, Newcastle disease, swine vesicular disease, vesicular stomatitis, high pathogenic avian influenza, rabbit haemorrhagic disease, lumpy skin disease, classical swine fever, contagious bovine pleuropneumonia, Rift valley fever, sheep pox and goat pox, rinderpest, peste des petits ruminants, foot-and-mouth disease [7]. These infections result in huge economic losses due to the direct and indirect damage, as well as due to the imposition of trade restrictions.

In particular, an epidemic of classical swine fever in the Netherlands in 1997 led to the destruction of 10 million pigs; the estimated damage was US $2.3 billion [8]. Foot-and-mouth disease was responsible for pig industry collapse in Taiwan in the same year. The disease affected more than 6 thousand farms, 4 million pigs were depopulated, losses amounted to US $560 million [9]. The financial losses associated with a foot-and-mouth outbreak in Great Britain in 2001 amounted to £3.1 billion (US $4.4 billion) only for agricultural sector and food industry [10]. An example of the negative effect of transboundary animal diseases on the economy is an ASF epidemic on the island of Hispaniola in 1978. Total pig depopulation on the island resulted in a dramatic fall of rural population living standards [11]. The situation recurred in 2021 after ASF introduction at first to the Dominican Republic and then to the Republic of Haiti. To ensure timely disease containment, TADs shall be notifiable to the World Organisation for Animal Health [12].

According to Order of the Ministry of Agriculture of the Russian Federation No. 62 of 9 March 2011, TADs are included in the List of contagious and other animal diseases [13].

While infection transmission was limited to its natural ranges in the past years, there are practically no natural barriers for the spread of TADs, first and foremost zoonotic and anthroponotic ones, under the new conditions of active international trade and logistics flows [14].

Official trade in animals and animal products is regulated by international and national legislation. But it is almost impossible to control the illegal movement of animals in informal trade, which results in transboundary transmission of infections. The most common source of infection is meat products; besides, fomites also play a role. Live animals can be a TAD source in case of their contacts with healthy livestock on shared pastures, especially in the mountain areas [15, 16].

In recent years, emerging infections have been increasingly reported. This not only changes the geography and structure of global epidemiology, but also dictates the need to rethink measures to prevent the introduction and spread of animal diseases and methods for their eradication, as well as to search for scientifically sound approaches to decision-making.

MATERIALS AND METHODS

The studies involved the collection and analysis of information on the epidemic situation, the application of probability and risk assessment methods with respect to infectious animal disease introduction to the Russian Federation and pathogen-free areas of the country, methods and practices of managerial decision-making in the veterinary and other fields of activities. The paper also presents the characteristic of TADs. The following commonly accepted data analysis methods were used: compilation and formalization, a comparative analysis method, methods of descriptive statistics.

RESULTS AND DISCUSSION

Transboundary animal diseases are a global challenge. At the same time, the scientific papers available do not fully reflect the specific epidemiological features of such infections, the patterns of their spread within a country or a group of countries, in particular the risk they represent for pathogen-free areas. The preparedness of the Veterinary Services of the countries and regions for proper and rapid detection, investigation and control of outbreaks is important for prevention of transboundary animal disease introduction via different pathways. The analysis performed showed that many countries, especially the developing ones, do not have adequate veterinary and diagnostic capacities to undertake the necessary actions [15, 17–24]. However, in case of introduction of some highly dangerous diseases, the above-mentioned measures turn out to be ineffective, even when taken in the developed countries. For example, at the time of ASF (genotype II) spread in the European Union and China, no progress was made in the identification of the source of infection in any of the affected countries (Hungary, Romania, Bulgaria and Belgium).

The epidemiological analysis methods employed are often framed by guidelines that are descriptive in nature. Only in the beginning of the twenty-first century, papers appeared, in which state-of-the-art geoinformation research techniques, computer programmes and technologies (for example, ArcGIS) began to be used for the analysis of epidemic spread among livestock [25, 26]. The applied use of the geoinformation system in the veterinary field involves the visualization of data on outbreak occurrence/spread, the generation of dynamic and planimetric maps, the identification of correlation between morbidity trends and economic, climatic, geographical, social and other factors [27]. The system allows for the analysis and prediction of morbidity spread, the establishment of the cause-and-effect relationship between increased morbidity and environmental-geographical risk factors, as well as the identification of geographical factors of localization and the extent of highly dangerous livestock disease spread in order to provide a scientific basis for the targeted monitoring of the epidemic situation, etc. [28].

The phylogenetic analysis of infection agents enables the identification of the most probable virus introduction sources and transmission pathways. For example, the phylogenetic analysis of a British isolate of FMD virus (2001) demonstrated its similarity to a South African one [24, 29]. North American strains of porcine epidemic diarrhea virus were found to be similar to the Chinese ones [30]. The genetic analysis of an ASF genotype II agent from China revealed its probable Eastern European origin [31].

The staff members of the Information Analysis Centre of the FGBI "ARRIAH" undertake great efforts towards justification of possibilities and application of modern analysis methods for animal disease spread prediction. The specialists collect and analyze information on the epidemic situation in the foreign countries, analyze the risk of highly dangerous disease introduction to the Russian Federation, in particular during the import/export of animals and agricultural products; they are also involved in mapping, modelling, data base creation and maintenance.

The ArcGIS add-in facilitating the identification of spatio-temporal regularities has found its practical use in the veterinary field. Being based on the notion of the spatio-temporal cube, it enables the detection of temporal trends of increase/decrease in outbreak concentration on the basis of their positional relationship, the analysis of locations and trends of hot spot occurrence, as well as the analysis of data in each particular location.

The following ArcGIS integral geospatial statistics tools are used for the detection and visualization of spatio-temporal disease spread trends: standard deviational ellipse, standard distance, mean center. The geospatial data analysis allows for the detection of spread trends, the identification of risk factors, epidemic forecasting [28].

The geographical approach helps to create geospatial-referenced data bases on animal diseases. Data visualization through maps provides a visual presentation of the epidemic situation with the possibility of preliminary visual analysis thereof [32].

The "trend-based Poisson random walk" model is used to calculate the prognostic values of the number of ASF outbreaks. Modelling is performed with @Risk software using the Monte Carlo simulation technique with 10,000 iterations. The modelling result is presented as a mean expected number of outbreaks, as well as 95% confidence interval [33].

Bifurcation analysis technique is also applied [14].

The application of descriptive routine and newly developed methods allowed to conclude that the probability of TADs occurrence is influenced by several factors:

– the presence of susceptible animals;

– animal population density;

– provision of appropriate recording and identification of animals;

– geographical environment;

– climatic conditions of a region;

– the presence of infection transmission vectors;

– animal management system and animal production management;

– anthropogenic factor activity;

– animal disease control methods applied;

– the level of the Veterinary Service performance;

– the existence of the normative framework for TADs control;

– the existence and implementation of federal and regional programmes;

– monitoring of infectious animal disease agent circulation;

– overall development level of a region/country;

– the extent of inter-agency collaboration;

– implementation of close control and surveillance over animal and animal product movement in compliance with the Decision on the establishment of statuses of the Russian Federation regions with respect to contagious animal diseases and conditions for the movement of commodities subject to official veterinary surveillance;

– the level and consistency of awareness-raising activities among the general public regarding the threat of contagious animal diseases, in particular transboundary ones, as well as the economic impact of their introduction and spread [4, 5, 34–38].

All the aforementioned and some other mathematical methods of epidemic situation analysis are used by the Veterinary Service to assess the risk of TAD introduction to the previously disease-free regions of the Russian Federation and timely prevent the threat of their spread. The timely implementation of anti-epidemic measures in case of an outbreak is the key factor for prevention of the disease spread across the pathogen-free area.

Risk is defined as the probability of an undesirable outcome. This potential is frequently employed to forecast various situations.

Risk assessment is a scientific method for the calculation, with the highest possible objectivity, of the harmful impact of the identified hazard or risk source on the health of humans, animals or the economy. A risk factor is a biological, chemical or physical agent or actions that may inflict harm to, or have a negative effect on, health/performance.

Risk analysis comprises three independent, but closely related, elements: risk assessment, risk factor management, risk communication.

Methodologically, there are the following risk assessment approaches: qualitative, semi-quantitative and quantitative. A qualitative method is the simplest and lowest cost one, it allows to quickly obtain information in its general form. Such risk analysis method ("decision tree") was suggested in the USA in the late 1950s. The analysis of agent introduction risk performed with a qualitative method in order to assess the probability of the agent spread involves the use of system modelling.

The semi-quantitative risk assessment seeks to rank risk levels (high, medium, low) based on the score estimates generated by a group of experts.

It should be noted that a semi-quantitative method is more informative, but requires accurate data, time and special training [21, 39–45]. Risk assessment can help to identify pathogen introduction pathways and potential impact. But qualitative information on unofficial disease introduction pathways is either absent or can be incomplete, and this makes it difficult to measure actual risks. However, this knowledge is necessary for the development of awareness-raising, prevention and epidemiological surveillance programmes based on actual risks [46].

The above-mentioned methods complement one another and are applied simultaneously during decision-making (risk assessment). A qualitative analysis allows to assess the risk of disease introduction to the previously disease-free area, a quantitative method is used to assess the potential disease spread and associated losses, and a semi-quantitative method is employed to assess the overall risk in such situation [47]. All this can be regarded as information support for managerial decision-making process.

Making a decision is the most critical moment. Decision-making is choosing among multiple alternative courses of action to achieve the target goal as the final stage of managerial process. It is essential that a decision-maker has confidence that the decision-making procedure is correct and desirable. The main stages in the managerial decision-making process include: setting of the goal, assessment of the situation, identification of the problem and making a decision to resolve it [48]. The decision-maker should understand the methods supported by theoretical and practical knowledge on decision-making, in particular in the veterinary field, be competent to identify approaches to maintain disease freedom of relevant areas and prevent the entry of TADs agents, be able to apply theoretical knowledge to analyze disease manifestations, to comprehensively utilize intellectual tools to address the arising practical issues.

Analytical Hierarchy Process (AHP) is a mathematical tool for a qualitative systematic approach to handle challenging problems in decision-making. Rather than prescribing a "correct" decision, AHP helps the decision-maker to interactively find the variant (alternative) that best suits the decision-maker's understanding of the problem and requirements to resolve it. This method was developed by Thomas Lewis Saaty, an American scientist, in 1970s [49, 50]; since then it has been actively refined and widely used in practice. Analytical Hierarchy Process can be used not only to compare objects, but also to address more complicated management and prediction challenges [51].

Hierarchy is a system, the levels of which are arranged and numbered in such a way that:

1) the lowest level contains the ranking alternatives;

2) nodes of levels with greater numbers can dominate only the nodes of levels with lesser numbers.

Thus, the links in the hierarchy define one-direction pathways – from the top to the alternatives via intermediate levels represented by nodes-factors (Fig.).

The main advantage of AHP is its versatility – this method can be used to tackle various tasks such as the analysis of possible scenarios of the situation development, resource allocation, client ranking, as well as HR decision-making.

The main disadvantage of AHP is the need for large amounts of information from experts. This method is best suited for cases when the major portion of data is based on the decision-maker's preferences during the process of selection of the best decision from among multiple alternatives.

In a typical decision-making situation:

– several decision variants are considered;

– a criterion is established, based on which the extent, to which one or another decision is appropriate, is determined;

– circumstances, in which the problem is addressed, as well as reasons that influence making one or another decision, are known.

Goal setting in AHP application: let us assume that there are multiple alternatives (decision variants): $V_1, V_2, \dots V_k$. For our goal of determining TAD risk, these are high, moderate and low. Each alternative is assessed based on the set of criteria: $C_1, C_2, \dots C_n$. For example, the following assessment criteria are used for ASF introduction risk analysis: feed, contacts with wild animals, contacts with domestic animals, contacts with blood-sucking insects, anthropogenic interference, transport-associated criterion and housing conditions. It is required to determine the level of risk of the disease introduction to the previously free areas.

Let us consider the steps of AHP application.

Step 1 is the preliminary ranking of criteria, as a result of which they will be ranked in descending order of their importance (significance).

Step 2 is the pair-wise comparison of the criteria according to their importance using a nine-point scale and an appropriate $n \times n$ matrix (table).

The pair-wise comparison system yields the result that can be represented as an inverse symmetric matrix. A matrix element (i, j) is the intensity of the hierarchy element i with respect to the hierarchy element j, which is estimated using a 1–9 intensity scale, where estimates mean the following:

– equal importance – 1;

– moderate dominance – 3;

– significant dominance – 5;

– strong dominance – 7;

– very strong dominance – 9;

– for intermediate values even numbers are used – 2, 4, 6, 8.

The following questions are mainly asked during the pair-wise comparison of the elements A and B:

– which of them is more important or has a greater impact;

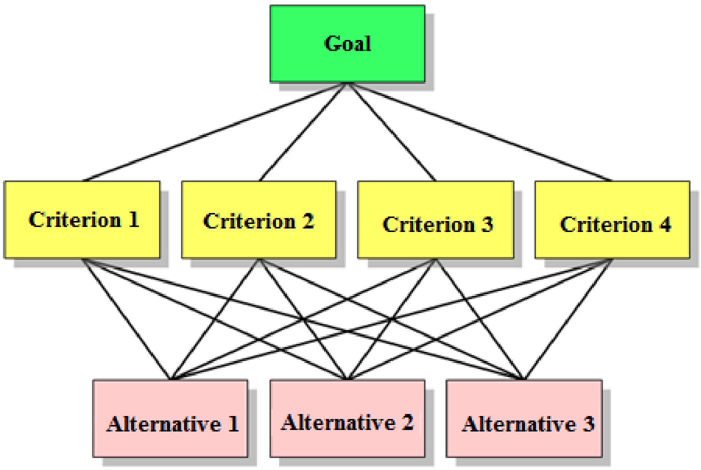

Fig. Simple AHP hierarchy.
To avoid confusion in AHP diagrams, links connecting alternatives and their covering criteria are often omitted or artificially reduced in number

– which of them has a higher probability;

– which of them is more preferable?

Step 3 is the construction of a matrix. If the element i is more important than the element j, a whole number is entered in the C_i:C_j cell corresponding to the row i and column j, and the reciprocal value is entered in the C_j:C_i cell corresponding to the row j and column i (Table 1).

For example, if the weight of the criterion C_1 (feed) is moderately higher than that of C_4 (animal movement), 3 is entered in the C_1:C_4 cell (at the intersection of the first row and the fourth column), and the reciprocal value (1/3) is entered in the C_4:C_1 cell (the fourth row, the first column). If the element j is more important than the element i, a whole number is entered in the C_j:C_i cell, and the reciprocal value is entered in the C_i:C_j cell. If i and j are judged to be equal, 1 (unity) is entered in both cells.

The table is filled in row by row, starting from the most important criterion. At first, whole number estimates are entered, and the corresponding fraction estimates (being the reciprocals of the whole numbers) are entered automatically. The more important a criterion is, the more whole number estimates will be entered in the corresponding

Table 1
Model table for comparison of ASF introduction risk criteria

	C_1	C_2	…	C_n	Geometric means	Normalized priority vector, NPV (formula 3)
C_1						
C_2						
…						
C_n						
Total					formula 2	
λ_{max}	formula 4					
Consistency index, CI	formula 5					
Consistency ratio, CR	formula 6					

row of the matrix, and these estimates will be higher. Since each criterion is equal to itself in importance, the main diagonal of the matrix will always consist of unities. It is obvious that the sum of components is equal to unity. Each component of the normalized priority vector (NPV) represents an importance estimate for the corresponding criterion (for example, the first component represents the importance estimate for the first criterion).

Geometric mean calculation for each row of the matrix:

$$a_1 = \sqrt[n]{\text{product of the 1}^{st}\text{ row elements}};$$

$$a_2 = \sqrt[n]{\text{product of the 2}^{nd}\text{ row elements}};$$

$$\dots$$

$$a_n = \sqrt[n]{\text{product of the n}^{th}\text{ row elements}}. \quad (1)$$

Calculation of the sum of geometric means:

$$\Sigma a_j = a_1 + a_2 + \dots + a_n. \quad (2)$$

NPV component calculation:

$$1^{st}\text{ NPV component} = \frac{a_1}{(\Sigma a_j)};$$

$$2^{nd}\text{ NPV component} = \frac{a_2}{(\Sigma a_j)};$$

$$n^{th}\text{ NPV component} = \frac{a_n}{(\Sigma a_j)}. \quad (3)$$

A check for consistency of local priorities by calculating three parameters:

– matrix eigenvalue:

$$\lambda_{max} = \Sigma\text{ of }1^{st}\text{ column} \times 1^{st}\text{ NPV} + \Sigma\text{ of }2^{nd}\text{ column} \times 2^{nd}\text{ NPV} + \dots + \Sigma\text{ of n}^{th}\text{ column} \times n^{th}\text{ NPV}; \quad (4)$$

– consistency index:

$$CI = \frac{(\lambda_{max} - n)}{n - 1}; \quad (5)$$

– consistency ratio (%):

$$CR = \frac{CI}{RI}, \quad (6)$$

where RI is random consistency index, which is determined theoretically for a case when estimates in the matrix are presented randomly and depends on the matrix size only, as shown in Table 2 (*step 4*).

Estimates in the matrix are considered to be consistent when CR ≤ 10–15%; otherwise, they should be reconsidered.

Step 5 is the pair-wise comparison of the variants (levels of risk) for each criterion in the same way as the criteria have been compared, and the corresponding tables are filled in.

A check for consistency of local priorities is carried out for each table by calculating three parameters (step 4).

Step 6 is the determination of the global criterion (priority) for each variant (levels of risk):

$$C(V_1) = V_1\text{ for }1^{st}\text{ crit.} \times 1^{st}\text{ NPV} + V_1\text{ for }2^{nd}\text{ crit.} \times 2^{nd}\text{ NPV} + \dots + V_1\text{ for n}^{th}\text{ crit.} \times n^{th}\text{ NPV}. \quad (7)$$

$C(V_2)$, $C(V_3)$ … $C(V_k)$ are calculated in a similar way, but V_1 in the expression should be replaced by V_2, V_3 … V_k, respectively. Table 3 is filled in.

Step 7. Determination of the best judgement, for which C value is the highest.

Step 8. The check of the judgement for its consistency:

– calculation of overall consistency index:

$$OCI = CI_1 \times 1^{st}\text{ NPV component} + CI_2 \times 2^{nd}\text{ NPV component} + \dots + CI_n \times n^{th}\text{ NPV component}; \quad (8)$$

– calculation of overall consistency ratio:

$$OCR = \frac{OCI}{ORI}, \quad (9)$$

where ORI is determined according to Table 1 at the level of RI for the matrices of comparison of the variants according to the criteria. The judgement is considered to be consistent when OCR ≤ 10–15%; otherwise, the matrices of comparison of the variants according to the criteria should be revised.

An example is the assessment of risk of TAD introduction to the previously free areas.

Let us assume that it is required to determine the level of risk of TAD introduction to the previously free region 1.

Table 2
Random consistency index

Matrix size	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 3
Model table – calculation of final priorities

	C_1	C_2	…	C_n	Final priorities (formula 7)
	1st NPV component values from Table 2 are indicated	2nd NPV component values from Table 2 are indicated		nth NPV component values from Table 2 are indicated	
V_1					$C(V_1)$ =
V_2					$C(V_2)$ =
…					…
V_k					$C(V_k)$ =
CI	CI_1 value for C_1 is indicated	CI_2 value for C_2 is indicated	…	CI_n value for C_n is indicated	the sum of the column is indicated
OCI	is calculated according to formula 8				
OCR	is calculated according to formula 9				

Table 4
Comparison of transboundary animal disease introduction risk criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Geometric means	NPV
C_1	1	7	7	7	7	7	7	5.3	0.5
C_2	1/7	1	5	1	7	5	1	1.6	0.15
C_3	1/7	1/5	1	1/5	1/3	1/3	3	0.4	0.04
C_4	1/7	1	5	1	5	3	1	1.4	0.13
C_5	1/7	1/7	3	1/5	1	1/3	1/3	0.4	0.04
C_6	1/7	1/5	3	1/3	3	1	1	0.7	0.07
C_7	1/7	1	1/3	1	3	1	1	0.8	0.07
TOTAL (sum)	1.9	10.5	24.3	10.7	26.3	17.6	14.3	10.6	1
λ_{max}	8.17								
CI	0.19								
CR	0.14								

On 14 January 2021, 12 dead wild boars infected with a TAD agent were detected in the neighbouring region 2 close to the border with the free region.

On 25 February 2021, the TAD agent genome was detected in the sausage brought to the free region 1 from the distant region 3.

On 14 October 2021, it was reported that veterinarians had detected infected animal products in the previously free region 1. The TAD agent genome was detected during laboratory tests of frozen meat delivered to the region 1 from the region 4, to which, judging from documents, the product had been delivered from the region 5.

Here we note three alternatives: V_1 – high risk, V_2 – moderate risk and V_3 – low risk. Each alternative is assessed using the following list of criteria: C_1 – feed, C_2 – anthropogenic interference, C_3 – contacts with wild animals, C_4 – contacts with domestic animals, C_5 – contacts with blood-sucking insects, C_6 – housing conditions, C_7 – transport-associated criterion.

The pair-wise comparison of the criteria according to their importance is carried out using a nine-point scale and a 7 × 7 matrix. The facts given above should also be taken into consideration.

Table 4 is filled in row by row, starting from the most important criterion, using the formulas (2–6). RI value according to Table 2 will be 1.32.

The estimates in the matrix can be considered consistent, since CR = 0.14 falls within CR ≤ 10–15%.

When comparing the variants (levels of risk) with one another, we will consider them to be equally probable.

Then we determine the best judgement, for which the value of each criterion is the highest.

Based on the highest sum of the column for V_1 (31 points), we conclude that the risk of TAD agent introduction to the free region 1 is high.

The calculation of overall consistency ratio according to the formula (9) gives OCR = 0.14% and the judgement can therefore be considered consistent.

Table 5
Comparison of criteria for transboundary animal disease risk level

	V_1	V_2	V_3
C_1	7	3	1
C_2	7	3	1
C_3	7	3	1
C_4	1	1	1
C_5	1	1	1
C_6	1	1	1
C_7	7	3	1

CONCLUSION

Given the interconnectedness and dense logistics network among the countries as regards trade in live animals and animal products, the introduction and further spread of highly dangerous diseases, in particular transboundary ones, to the disease-free areas, remain a serious threat to the entire livestock industry at present and will remain such in the near future.

The potential application of Analytical Hierarchy Process as a decision-making tool for assessment of the risk of transboundary animal disease occurrence and introduction will allow to adequately understand the level of threat and undertake preventive measures in advance. However, when using this methodology, account should be taken of the need for reliable quantitative and qualitative data.

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