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Construction of index system for external risk factors of disease on large-scale farm based on the analytic hierarchy process

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Abstract

Animal health risk analysis technology on large-scale farm is becoming more important, but the assessment of relevant external risk factors of disease spreading into pig farm is an complex multi-dimensional process. The analytic hierarchy process (AHP) has been accepted as a robust and flexible multi-criteria decision-making tool for dealing with complex decision problems. On this study, The index system of external risk factors on large-scale farm is built based on AHP. The result shows that farm management practices, Biosecurity and site are major risk factors and reveals AHP can be used in animal risk analysis for disease control and prevention.

Keywords: Analytic hierarchy process; pig farm ; disease ; risk factor ; index system;

1. Introduction

With the rapid development of China's pig industry, it has become the pillar in China's agriculture and agricultural economy. China's pig farm has been shift from the amount-speed type to be the quality-efficiency type. With the increasing number of China's large-scale farms, the animal diseases are becoming more complicated for much reason [1,2]. This condition is not only caused huge economic losses to the aquaculture industry, but also resulted in potentially public health problem. Such as diseases of respiratory system in swine which are the most serious disease, and reproductive disorders, diarrhea or other diseases. By the study of the advanced control concepts and techniques of disease and the overview of our Local conditions of diseases and large-scale farms, the development of large-scale farm animal disease prevention and control strategies is believed to be an inevitable trend [1,2].

Animal health risk analysis technology was used by developed countries in Europe and the United States to prevent and control large-scale farms epidemic, and a remarkable success was achieved [3,4].

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These techniques are developed based on the production and management program of scale farm, and a comprehensive and systematic identification of pathogens or risk factors. The first step of risk analysis for them is making a qualitative or quantitative assessment of risk factors, and the next step involves making a scientific risk management measures which can reduce or eliminate the risk of animal disease based on the first assessment's results. According to this, the assessment of relevant external risk factors of disease spread into pig farm was found to be an intrinsically complex multi-dimensional process [5].

The analytic hierarchy process (AHP), developed by Saaty, is a decision making method for prioritizing alternatives when multiple criteria must be considered. It has been extensively applied all over the world to a variety of fields such as agriculture, predictive maintenance, web-service [6], medical and so on. Basically, AHP has three underlying concepts: structuring the complex decision problem as a hierarchy of goal, criteria and alternatives, pair-wise comparison of elements at each level of the hierarchy with respect to each criterion on the preceding level, and finally vertically synthesizing the judgements over the different levels of the hierarchy [7].

Firstly, the external risk factors of disease spread into farm were determined based on the characteristics of animal epidemics. And the next step is assuming the specific weight regarding various factors that affect spread conditions with the questionnaire. Finally, according to the analytic hierarchy process, the index system of risk factors for disease incoming farms was build.

2. Research methodology

The Analytic Hierarchy Process (AHP) is designed to structure a decision process in a scenario affected by multiple independent factors. In the analysis, a complex problem can be divided into several sub-problems that are organized according to hierarchical levels, where each level denotes a set of criteria or attributes related to each sub-problem. The top level of the hierarchy denotes the goal of the problem and the intermediate levels denote the factors of the respective upper levels. Meanwhile, the bottom level contains the alternative or actions considered when achieving the goal [8,9,10]. Some key and basic steps involved in this methodology are [11]:

Define the problem.

Broaden the objectives of the problem or consider all actors, objectives and its outcome.

Identify the criteria that influence the behavior.

Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Compare each element in the corresponding level and calibrate them on the numerical scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion with respect to which they are compared. The scale are shown in Table 1 [9]

Table 1 Nine-point scale for pair wise comparison

Intensity of pair wise comparison	Importance
1	Equal importance, two activities contribute equally to the object
3	Moderate importance, slightly favors one over another
5	Essential or strong importance, strongly favors one over another
7	Demonstrated importance, dominance of the demonstrated importance in practice
9	Extreme importance, evidence favoring one over another of highest possible order of affirmation
2,4,6,8	Intermediate values, when compromise is needed

Perform calculations to find the maximum eigenvalue, consistency index CI, consistency ratio CR, and normalized values for each criteria/alternative.

$$CI=(\lambda_{max}-n)/(n-1) \qquad (1)$$

Where λ_{max} is the maximum eigenvalue and n is the number of factors in the judgement matrix. Accordingly, Saaty (1980) defined the consistency ratio (*CR*) as

$$CR=CI/RI \qquad (2)$$

Where *RI* is the consistency index of a randomly generated reciprocal matrix from the 9-point scale and is shown in Table 2

Table 2 Average random index for corresponding matrix size

n	1	3	4	5	6	7	8	9
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

When $CR = CI / RI < 0.10$, that we say the judgment matrix has satisfied consistency, if its larger than 0.1， there may be one or more extreme judgments resulting in a highly skewed distribution for the judgment. In this case, the mean of the distribution may not be an appropriate value to use. you will need to adjust the judgment matrix has the satisfied consistency.

In this study, the specific weight regarding various factors that affect spread conditions is determined by literature review, expert consultation and discussion with the pig farm staff. 35 questionnaires were prepared and sent to 20 experts of Animal health inspection 、 veterinary research institutes and 15 staffs of pig farm. At the end, the recovery rate was 100%, among them, 4 invalid questionnaires were deleted after a preliminary analysis, and the remaining 31 valid questionnaires were received. The various factors regarding disease incoming of questionnaires were determined based on the figure 1. We can see from the figure 1 that the problem in a hierarchy of different levels constituting goal, criteria and sub-criteria levels.

The hierarchical structure and all levels of the judgment matrix model was edited and calculated by Excel analysis software.

3. Modeling of the external risk factors that affect spread conditions Index using the Analytic Hierarchy Process

The index system was set based on three principles, The first is the principle of comprehensiveness， the common epidemic pathogen of the respiratory and reproductive disorders and the popular features of large-scale farm production and management methods were combined and full consideration to each of the factors if it have possibility of causing epidemics was given too. The second is the principle of feasibility, by the field survey of the different forms of large-scale pig farm facilities and management, operational factors was established based on the diseases and the pig profiles, according to this, the subjective affection in the evaluation process was reduced and the authenticity of the evaluation results was guaranteed. The third is the principle of combining qualitative and quantitative investigation, some indicators factors are so difficult to quantify that we can only to use qualitative methods to evaluate, this way of combination of qualitative and quantitative methods will be more in line with the actual operation, and could be better of ensure the results of the evaluation to be more authenticity.

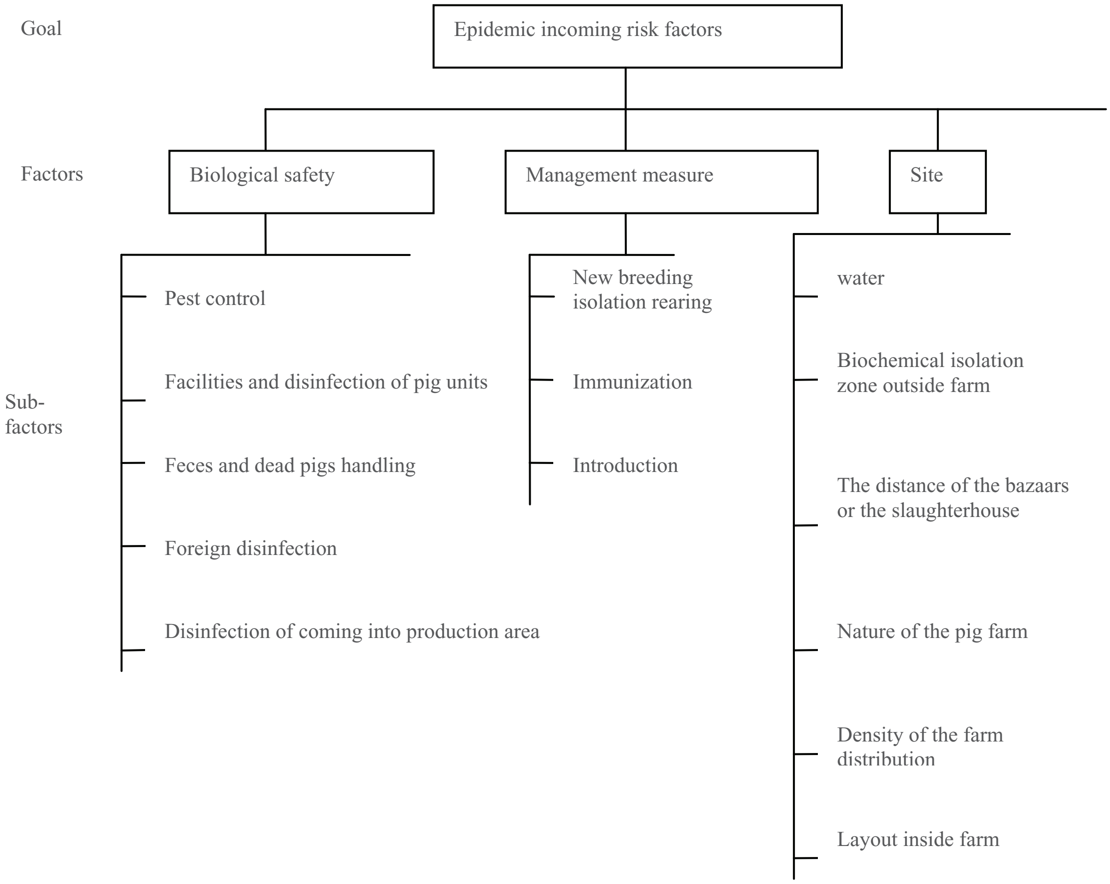

Fig.1.Hierarchy diagram

The index of Ⅰ level was determined follows the procedure that was proposed before by the fundamental scale of Saaty, The criteria were first compared between them with respect to the goal. The results of this comparison are recapped in Table 3. Afterwards, the index of Ⅱ level was determined on the same way and the elements at this level have been compared with respect to the upper-level elements. Tables 4–6 recap the comparisons between sub- criteria levels with respect to each criterion: management factor, biological safety factor, site factor. The total weight of index system was determined based on the results of the above level, the results are shown in table 7.

Table 3 Pair wise comparison of the index of Ⅰ level

Weight determined of risk factors	site	biological safety	Management measure	*Weight (Wi)*
site	1	1/5	1/6	0.078
biological safety	5	1	1/3	0.287
Management measure	6	3	1	0.635

The analysis was done through Excel software. λ_{max}=3.094, *CR*=0.081<0.10.

Table 4 Pair wise comparison of Management measure factor

Management measure factors	New breeding isolation rearing	immunization	introduction	*Weight (Wi)*
New breeding isolation rearing	1	1/2	1/6	0.102
Immunization	2	1	1/5	0.172
Introduction	6	5	1	0.726

The analysis was done through Excel software. λ_{max}=3.029, *CR*=0.025<0.10

Table 5 Pair wise comparison of biological safety factor

Biological safety factor	Pest control	Facilities and disinfection of pig units	Feces and dead pigs handling	Foreign disinfection	Disinfection of coming into production	*Weight (Wi)*
Pest control	1	1/3	1/4	1/5	1/6	0.045
Facilities and disinfection of pig units	3	1	1/2	1/4	1/5	0.087
Feces and dead pigs handling	4	2	1	1/2	1/4	0.146
Foreigner disinfection	5	4	2	1	1/3	0.246
Disinfection of coming into production area	6	5	4	3	1	0.475

The analysis was done through Excel software. λ_{max}=5.021, *CR*=0.044<0.10

Table 6 Pair wise comparison of site factor

Site factors	water	Biochemical isolation zone outside farm	The distance of the bazaars or the slaughterhouse	Nature of the pig farm	Density of the farm distribution	Layout inside farm	*Weight (Wi)*
water	1	1/3	1/5	1/5	1/5	1/7	0.027
Biochemical isolation zone outside farm	3	1	1	1/3	1/3	1/5	0.063
The distance of the bazaars or the slaughterhouse	5	1	1	1/3	1/3	1/5	0.068
Nature of the pig farm	5	3	3	1	1	1/5	0.143
Density of the farm distribution	5	3	3	1	1	1/5	0.143
Layout inside farm	7	7	7	7	7	1	0.554

The analysis was done through Excel software. λ_{max}=6.410, *CR*=0.067<0.10

Table 7 Total level of sorting

Total level of sorting	Management measure	Biological safety	Site	Wi	Sequence
	0.635	0.287	0.078		
Introduction	0.726			0.460	1
immunization	0.172			0.109	3
New breeding isolation rearing	0.102			0.064	5
Disinfection of coming into production area		0.475		0.136	2
Foreigner disinfection		0.246		0.070	4
Feces and dead pigs handling		0.146		0.042	7
Facilities and disinfection of pig units		0.087		0.025	8
Pest control		0.045		0.013	11
Layout inside farm			0.554	0.043	6
Density of the farm distribution			0.143	0.011	9
Nature of the pig farm			0.143	0.011	10
The distance of the bazaars or the slaughterhouse			0.068	0.005	12
Biochemical isolation zone outside farm			0.063	0.005	13
Water			0.027	0.002	14

The analysis was done through Excel software. CR=0.038<0.10

4. Conclusion

The index system of external risk factors of disease spread into pig farm was constructed by this research. This index system involves one goal, three indexes in criteria and fourteen indexes in sub-criteria. From the table 4-table 7 we can see, The risk factors' priority list for the influence in disease incoming were: Management measures factor which is the most main risk factors, followed by biological safety factor; The last is site factor. Among them, introduction, immunization and disinfection of going into the production areas are the first three more important factors. In addition, we need to pay attention to the site area factor. Because when it was once established, it was difficult to change, this characteristic decided it though not have a big weighting in the index system, but once the site wrong, it will influence biological safety management effect in the future.

Currently, for the scale and intensive breeding industry, Livestock epidemic diseases are more various. With the population of porcine circovirus 2(PCV2) and PRRS, it result in pigs dual immunosuppressive, and result in several distinct syndromes and diseases including post-weaning multisystemic wasting syndrome(PMWS), porcine dermatitis and nephropathy syndrome(PDNS),reproductive failure, porcine respiratory disease complex and so on, and make the disease to be so difficult to control. Under this situation, they need to attach the measures of standardization of biological safety.

In order to solve the difficulties of data collection in the animal health risk analysis, the authors try to apply the analytic hierarchy process into establishment of risk factors, The analytic hierarchy process is a way combining the qualitative and quantitative analysis, so that all farms can determine all the weights of external risk factors based on their own situation on the basis of this index system to evaluate the pig's own risk factors.

The field research and a large number of documents was expanded, but the most was qualitative analysis. The more effective and efficient way of collecting the required data should be considered and should have a further investigation.

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