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Using and Molding of Agricultural Machinery Safety Management Evaluation based on Fuzzy Analytic Hierarchy Process

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Abstract: As the level of agricultural mechanization in China continues to improve, the issue of agricultural machinery safety management is becoming increasingly prominent. Strengthening the safety management of agricultural machinery is of great significance for safeguarding the safety of farmers' life and property and the healthy development of agricultural mechanization. This paper combines the hierarchical analysis method (AHP) and the fuzzy evaluation method, and establishes the evaluation index system of agricultural machinery safety management by selecting 18 indexes from five aspects: industry management, basic situation of drivers, management of agricultural machinery, insurance coverage of agricultural machinery, and operating environment. The fuzzy comprehensive evaluation method was used to establish the evaluation model of agricultural machinery safety management, and the evaluation method was applied to Liaoning Province. The results show that the safety management level of agricultural machinery in Liaoning Province is excellent.

Keywords: Agricultural Machinery; Safety Management; Evaluation Index; Hierarchical Analysis; Fuzzy Comprehensive Evaluation

1. Introduction

In recent years, China's agricultural machinery has developed to the direction of large-scale, duplex operation and automation. At the same time, it is faced with such problems as complex and changeable operation environment, low cultural quality of operators, and weak safety awareness. The safety problem of agricultural machinery production has become increasingly prominent[1-3]. At present, the problem of safe operation of agricultural machinery is quite common in China, which has a certain degree of impact on the development of rural economy and has become an important factor restricting rural economic construction. Agricultural machinery safety propaganda and education is not in place, the safety production law is not perfect, the safety awareness of agricultural machinery operators is weak, agricultural machinery is not overhauled all the year round and other problems cause China's agricultural machinery safety production situation is still grim[4-5]. At present, China's agricultural machinery safety production is still far from stable and controllable as a whole. With the increasing attention of the state to the safety production of agricultural machinery, strengthening the safety management of agricultural machinery can effectively reduce the incidence of safety accidents of agricultural machinery, reduce the investment in agricultural production, improve the production efficiency of agricultural machinery, and promote the rapid development of agricultural economy. Therefore, we must realize the safe operation of agricultural machinery through scientific and standardized management, in order to constantly adapt to the needs of the development of the new situation. The research of agricultural machinery safety management evaluation has a certain guiding significance for agricultural machinery safety production.

At present, some scholars have carried out the work in establishing the index system of agricultural machinery safety management and agricultural machinery safety risk, and determining the index weight. used analytic hierarchy process (AHP) and comprehensive evaluation method to comprehensively evaluate various factors affecting the safety management of agricultural machinery and their work quality level, selected 16 indexes from four aspects of personnel quality, machinery status, management level and working conditions to construct the evaluation index system, and put forward the fuzzy comprehensive evaluation method for the safety management of agricultural machinery, The factors influencing the safety management of agricultural machinery and the overall work quality level were comprehensively evaluated. A quantitative method of agricultural machinery safety risk assessment was obtained using set pair theory[6]. The agricultural machinery safety risk evaluation index system, which comprehensively considers four first level evaluation indexes of mechanical quality, worker quality, production conditions and safety management, and 12 second level evaluation indexes of technical status and placement device, is analyzed and verified by taking agricultural machinery equipment of three production departments of an agricultural machinery enterprise as an example. Risk reduction strategy of agricultural machinery based on WSR was put forward which can effectively reduce the risk of agricultural machinery and enhance the safety of agricultural machinery[7]. These studies are of great significance to reduce the risk of agricultural machinery, guide the safety supervision of agricultural machinery, and provide scientific basis for the safety supervision of agricultural machinery.

In the aspect of safety management evaluation, analytic hierarchy process (AHP) is a commonly used evaluation method, which combines quantitative and qualitative methods. By comparing the relationship between various index, the complex problem is decomposed into several levels and several index[8-10]. These index are compared and calculated, and the index weight is reasonably determined to realize the evaluation analysis, Fuzzy comprehensive evaluation (FCE) uses the methods of fuzzy mathematics and fuzzy statistics to make a scientific evaluation of safety management through comprehensive consideration of various factors affecting something[11,12]. In this paper, the analytic hierarchy process and fuzzy evaluation method are combined, considering the various factors of agricultural machinery safety management, the evaluation index system of agricultural machinery safety management is constructed, the weight of each index is determined, and the agricultural machinery safety management in Liaoning Province is evaluated, in order to provide reference for agricultural machinery safety management.

2. Overview of Study Area and Data Processing

2.1 Overview of the Study Area

Liaoning Province is located in the south of Northeast China, with a land area of about 1.459×10^6 km^2, of which the cultivated land area is about 4.1×10^6 hm^2, accounting for 27.65% of the land area in Liaoning Province. Liaoning Province has about 7200 cooperatives and agricultural machinery service organizations, and about 5.7×10^5 tractors, the total power is about 1.3×10^7kW, about 3×10^4 combine harvesters, the total power is about 2.1×10^6 kW. In recent years, there are about 23 accidents of agricultural machinery production in Liaoning Province every year, and the economic loss is about 1.12×10^6 yuan. The average death toll was 6 and the average number of injured was 21. As a large agricultural production province, Liaoning Province has a large area of cultivated land and a high level of mechanization in the whole process of agricultural production. Therefore, the safety management of agricultural machinery must be an important part of the safety production of agricultural machinery.

2.2 Data Sources and Processing

The main data sources of this paper are:

(1) survey data of County-Level Agricultural Machinery Management Department: through field survey, online questionnaire survey and other methods, the basic situation of agricultural machinery safety in Liaoning Province was collected. There were 16 survey points, and 16 questionnaires were collected. After screening, there were 16 effective questionnaires, and the effective rate of the questionnaire was 100%.

(2) Liaoning agricultural and rural department: to understand the general situation of agricultural machinery safety management in Liaoning Province. In this paper, when setting the evaluation index, we should not only consider the index of production operation, but

also consider the index of production management. Therefore, the questionnaire and research contents of agricultural machinery safety management include: agricultural machinery industry management, basic situation of agricultural machinery operators, agricultural machinery management, agricultural machinery working environment, agricultural machinery insurance, agricultural machinery accidents and other data.

Due to the different dimensions of the agricultural machinery safety management evaluation index values, the contribution rate to the evaluation results is also different[13]. When calculating the agricultural machinery safety management evaluation index, each index can not be simply accumulated, and each evaluation index must be standardized to eliminate the dimensional differences between the evaluation indexes[14]. After the data are sorted and summarized, the data are integrated.

3. Evaluation Index System

3.1 Methods and Steps

Fuzzy analytic hierarchy process (FAHP) evaluation method is based on the combination of fuzzy mathematics theory and analytic hierarchy process (AHP). AHP is a method of calculating weight, while fuzzy comprehensive evaluation method is a method of comprehensive evaluation of problems[15]. In this paper, the basic principle of analytic hierarchy process (AHP) is applied to construct the AHP model of agricultural machinery safety evaluation, and the corresponding safety evaluation index system is established. The characteristic vector of the mutual comparison matrix between the indexes is taken as the weight of the agricultural machinery safety evaluation factors. Based on the fuzzy mathematics theory, the membership function of the influencing factor set is constructed, and the fuzzy evaluation matrix of agricultural machinery safety is obtained, Then the evaluation result vector is calculated. Finally, through fuzzy comprehensive evaluation, the evaluation level of agricultural machinery safety management is obtained.

Table 1. Agricultural Machinery Safety Management Index System

Index system		
Target layer	First level index	Second level index
Safety management evaluation of agricultural machinery	Industry management index U_1	Implementation of agricultural machinery safety management system U_{11}
		Improvement of emergency response mechanism U_{12}
		Investment in work safety U_{13}
		Personnel allocation rate of safety supervision U_{14}
		Hidden danger and rectification U_{15}
	Driver basic information index U_2	Cultural quality of drivers U_{21}
		Technical quality of drivers U_{22}
		Training rate of drivers U_{23}
		License holding rate of drivers U_{24}
	index of agricultural machinery management U_3	Inspection rate of agricultural machinery U_{31}
		Qualified rate of agricultural machinery inspection U_{32}
		Age of agricultural machinery U_{33}
		Agricultural machinery safety inspection rate U_{34}
	index of agricultural machinery insurance coverage U_4	Coverage of agricultural machinery insurance U_{41}
	Working environment index U_5	Workplace conditions U_{51}
		Cross area operation rate U_{52}
		Allocation rate of safety protection devices U_{53}
		Warning signs U_{54}

3.2 Construction of Evaluation Index System

Agricultural machinery safety management evaluation index system is a comprehensive and comprehensive concept, which is a hierarchical structure composed of different aspects and different levels of index. Through extensive collection of evaluation indexes of Agricultural Machinery Supervision; agricultural mechanization, other management, according to the connotation and index screening principle of agricultural machinery safety management, and comprehensive expert opinions, five aspects including industry management, basic driver information, agricultural machinery management, agricultural machinery insurance coverage, and working environment were selected[16-18]. The evaluation index system of agricultural machinery safety management was established. The evaluation index system of this paper is divided into two levels, and the corresponding indexes of each level are shown in Table 1.

3.3 Index Weight Determination Method

Index weight refers to the importance relationship of each index under the same objective constraints. This study uses AHP to determine the index weight. According to the nature of the problem and the general goal to be achieved, the analytic hierarchy process (AHP) decomposes the problem into different constituent factors, and according to the correlation between the factors and the subordination relationship, the factors are aggregated and combined according to different levels to form a multi-level analytical structure model, so that the problem can be finally reduced to the lowest level (the scheme for decision-making Measures, etc.) relative to the highest level (overall goal), the determination of relatively important weights or the arrangement of relative advantages and disadvantages[19].

3.3.1 Compare and quantify

The experts compare the relative importance of six indexes in the same level index group {(U_1, U_2, U_3, U_4, U_5),(U_{11}, U_{12}, U_{13}, U_{14}, U_{15}), (U_{21}, U_{22}, U_{23}, U_{24}), (U_{31}, U_{32}, U_{33}, U_{34}), (U_{41}), (U_{51}, U_{52}, U_{53}, U_{54})},and quantify the comparison results with a scale of 1-9 (see Table 2).

Table 2. Rating Scales of Relative Importance of Index

Comparison results	Scaling
The two factors have the same importance	1
The former is more important than the latter	3
The former is more important than the latter	5
The former is more important than the latter	7
The former is more important than the latter	9
The intermediate value of the above adjacent judgment	2,4,6,8
If the ratio of the importance of factor i to factor j is a_{ij} Then the ratio of the importance of factor J and factor I is aij=1/aij	aji=1/aij

3.3.2 Determine index weight

The judgment matrix of pairwise comparison is constructed from the scale of quantitative results, and the weight of each index is determined by single order calculation of the judgment matrix. The first step of weight calculation is normalization:

1) Calculate the product Mi of the elements in each row of the matrix

$$M_i = \prod_{j=1}^{n} a_{ij} \quad i = 1,2,...,n \tag{1}$$

2) Calculate the product Mi of the elements in each row of the matrix

$$\overline{w_1} = \sqrt[n]{M_i} \quad i = 1,2,...,n \tag{2}$$

3)Normalize the vector $\overline{w_i}$=[$\overline{w_1}$,$\overline{w_2}$, ..., $\overline{w_n}$]

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n}\overline{W_i}} \quad i = 1,2,...,n \tag{3}$$

$W = [W_1, W_2, ..., W_n]^T$ is the weight vector.

4) Calculating the maximum eigenvalue of judgment matrix

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{AW_i}{W_i} \tag{4}$$

3.3.3 Consistency test of judgment matrix

In order to ensure the scientific and reliability of the calculation results, it is necessary to check the consistency of the judgment matrix. $CI = \frac{\lambda_{max} - n}{n-1}$, $CR = \frac{CI}{RI}$ are used. Where: λ_{max} is the largest eigenvalue of the judgment matrix; n is the order of judgment matrix; RI is the average random consistency value corresponding to n (see Table 3 for details). When $CR < 0.1$, it is considered that the judgment matrix has good consistency, otherwise the value of the elements of the judgment matrix should be adjusted.

Table 3. Value of Average Random Consistency Index RI

Order number	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3.4 Calculation of Index Weight

Table 4. Samples for Calculation of Weights of First Level Index Group

First layer index	U_1	U_2	U_3	U_4	U_5	W_i
Industry management index U_1	1	2	1/3	4	1	0.205
Driver basic information index U_2	1/2	1	1/2	2	1/2	0.128
index of agricultural machinery management U_3	3	2	1	6	2	0.396
index of agricultural machinery insurance coverage U_4	1/4	1/2	1/6	1	1/3	0.062
Working environment index U_5	1	2	1/2	3	1	0.210
Calculation of inspection items	n			5		
	λ_{max}			5.108		
	CI			0.027		
	CR			0.024		

Table 5. Index Weights of Agricultural Machinery Safety Management

First level index	group eight	Second level index	group weight	index weight
Industry management index U_1	0.216	Implementation of agricultural machinery safety management system U_{11}	0.185	0.04
		Improvement of emergency response mechanism U_{12}	0.098	0.021
		Investment in work safety U_{13}	0.185	0.04
		Personnel allocation rate of safety supervision U_{14}	0.185	0.04
		Hidden danger and rectification U_{15}	0.347	0.075
Driver basic information index U_2	0.115	Cultural quality of drivers U_{21}	0.123	0.014
		Technical quality of drivers U_{22}	0.228	0.026
		Training rate of drivers U_{23}	0.228	0.026
		License holding rate of drivers U_{24}	0.421	0.048
agricultural machinery management index U_3	0.397	Inspection rate of agricultural machinery U_{31}	0.166	0.066
		Qualified rate of agricultural machinery inspection U_{32}	0.334	0.133
		Age of agricultural machinery U_{33}	0.334	0.133
		Agricultural machinery safety inspection rate U_{34}	0.166	0.066
agricultural machinery insurance coverage index U_4	0.056	Coverage of agricultural machinery insurance U_{41}	1.000	0.056
Working environment index U_5	0.216	Workplace conditions U_{51}	0.222	0.048
		Cross area operation rate U_{52}	0.222	0.048
		Allocation rate of safety protection devices U_{53}	0.444	0.096
		Warning signs U_{54}	0.112	0.024

A questionnaire survey was conducted among 30 experts in the field of agricultural machinery safety management in China. They were invited to judge the importance of each index in the six index groups of the same level in the index system. The average value was taken to calculate the weight of each index. The calculation process is shown in Table 4. A total of 30 questionnaires were sent out and 30 questionnaires were collected. Table 4 only shows the calculation process of the weight vector of one expert for the comparison of the importance of index in the first level indicator group (U_1,U_2,U_3,U_4,U_5), where n = 5 in the calculation of detection items.

By using the analytic hierarchy process, 30 experts scored the importance of each group of index. After calculation, 30 weight vectors were obtained for each group of index, and the average value was taken to obtain the weights of all levels of index in the agricultural machinery safety evaluation index system (Table 5).

3.5 Evaluation of Agricultural Machinery Safety Management

3.5.1 Construction method of fuzzy comprehensive evaluation model

1)Determine index set: determine the factors that have influence on the evaluation object according to the evaluation index system, and the index set of constituent factors I= $\{u_1,u_2,\ldots,u_{ij},\ldots,u_{18}$.

2) Determine the evaluation set: establish the evaluation set $V=\{V_I,V_{II},\ldots,V_m\}$, m take IV, and the corresponding evaluation is V= [grade I, level II, level III, level IV], reflecting the change of the safety management level of agricultural machinery from superior to inferior.

The safety level of agricultural machinery of each index is "grade I, grade II, grade III and grade IV", and the interval represented by them is expressed by V_I、V_{II}、V_{III}、V_{IV}= { [100,75],[75,50],[50,25],[25,0] } respectively, which is sorted according to the score of comprehensive evaluation to reflect the change of safety level of agricultural machinery from excellent to poor.

3) Determining membership function

The membership function model used in this paper is

$$V_I(U_i)=\begin{cases}0, & U_i<\text{II}\\ \dfrac{U_i-\text{II}}{\text{I}-\text{II}}, & \text{II}\le U_i\le \text{I}\\ 1, & U_i>\text{I}\end{cases} \tag{5}$$

$$V_{II}(U_i)=\begin{cases}0, & U_i<\text{III} \text{ or } U_i>\text{I}\\ \dfrac{U_i-\text{III}}{\text{II}-\text{III}}, & \text{III}\le U_i\le \text{II}\\ \dfrac{\text{I}-U_i}{\text{I}-\text{II}}, & \text{II}<U_i\le \text{I}\end{cases} \tag{6}$$

$$V_{III}(U_i)=\begin{cases}0, & U_i<\text{IV} \text{ or } U_i>\text{II}\\ \dfrac{U_i-\text{IV}}{\text{III}-\text{IV}}, & \text{IV}\le U_i\le \text{III}\\ \dfrac{\text{II}-U_i}{\text{II}-\text{III}}, & \text{III}<U_i\le \text{II}\end{cases} \tag{7}$$

$$V_{IV}(U_i)=\begin{cases}1, & U_i<\text{IV}\\ \dfrac{U_i-\text{III}}{\text{III}-\text{IV}}, & \text{IV}\le U_i\le \text{III}\\ 0, & \text{III}<U_i\end{cases} \tag{8}$$

In the formula, I, II, III and IV respectively refer to the limits of each grading standard of each evaluation factor, and UI refers to the actual values of each index. The actual value of each evaluation index is brought into the corresponding membership function to obtain the membership matrix R(R is $m\times n$ order), According to the evaluation index system and evaluation grade, m=18,n=4.

4)Comprehensive evaluation: the comprehensive set B of fuzzy evaluation can be obtained by multiplying and accumulating the weight value w_i of each evaluation index and the relative membership value of the corresponding evaluation index. The fuzzy synthesis is completed by fuzzy synthesis weighted linear transformation. Where a is the index weight set, R is the membership matrix, and B is the comprehensive evaluation result. The membership matrix of four evaluation levels of agricultural machinery safety management is obtained, and then the agricultural machinery safety level is judged according to the maximum membership principle.

$$B_i=W_i\times R_i \tag{9}$$

3.6 The Evaluation of Agricultural Machinery Safety Management in Liaoning Province

According to the membership degree of index, the membership matrix R of the evaluation index of agricultural machinery safety management in Liaoning Province is obtained, as shown in Table 6.

The product of membership degree and weight is the evaluation result. According to the weight vector and membership degree, the evaluation results of agricultural machinery safety management in Liaoning Province are as follows.

3.7 Results and Analysis

The evaluation model of agricultural machinery safety management established in this paper is applied to evaluate the agricultural machinery safety management in Liaoning Province. According to the principle of maximum membership degree, the membership degree of agricultural machinery safety management in Liaoning Province is 0.45 in grade I, which belongs to grade I safety. From the first level index, the comprehensive score of industry management in grade I is 0.33. The investment of agricultural machinery safety management funds and the allocation rate of safety supervision personnel in Liaoning Province are better, but the main restricting factor is the low improvement rate of emergency response mechanism; The comprehensive score of Liaoning drivers' basic situation index in grade I safety is 0.39, the license holding rate of drivers is high, but the cultural quality and training rate of drivers are low; The comprehensive score of grade I safety of agricultural machinery management in Liaoning Province is 0.66, and Liaoning Province has a significantly higher level in agricultural machinery management; The comprehensive score of agricultural machinery insurance coverage in grade IV safety is 0.56. Agricultural machinery management departments often inspect agricultural machinery, and the qualified rate of agricultural machinery is high, but agricultural machinery insurance has not been fully implemented in Liaoning; The comprehensive score of grade I safety of working environment in Liaoning Province is 0.35. The cross regional operation rate in Liaoning Province is low, and the working environment is relatively safe, but the equipped rate of safety protection devices in the surrounding environment is low. Through the case analysis of agricultural machinery safety management in Liaoning Province, it can be seen that the established index system includes corresponding evaluation indexes, which can comprehensively reflect the breadth and depth of agricultural machinery safety evaluation.

Table 6. Membership Calculation Results of Agricultural Machinery Safety Management Index in Liaoning

Index	Membership degree calculation			
	Level I	Level II	Level III	Level IV
Implementation of agricultural machinery safety management system U_{11}	0.20	0.80	0.00	0.00
Improvement of emergency response mechanism U_{12}	0.00	0.20	0.80	0.00
Investment in work safety U_{13}	1.00	0.00	0.00	0.00
Personnel allocation rate of safety supervision U_{14}	0.56	0.44	0.00	0.00
Hidden danger and rectification U_{15}	0.00	0.00	0.37	0.63
Cultural quality of drivers U_{21}	0.00	0.00	0.90	0.10
Technical quality of drivers U_{22}	0	0.05	0.95	0.00
Training rate of drivers U_{23}	0.00	0.00	0.08	0.92
License holding rate of drivers U_{24}	0.92	0.08	0.00	0.00
Inspection rate of agricultural machinery U_{31}	0.26	0.74	0.00	0.00
Qualified rate of agricultural machinery inspection U_{32}	1.00	0.00	0.00	0.00
Age of agricultural machinery U_{33}	0.34	0.66	0.00	0.00
Agricultural machinery safety inspection rate U_{34}	1.00	0.00	0.00	0.00
Coverage of agricultural machinery insurance U_{41}	0.00	0.00	0.44	0.56
Workplace conditions U_{51}	0.55	0.45	0.00	0.00
Cross area operation rate U_{52}	0.97	0.03	0.00	0.00
Allocation rate of safety protection devices U_{53}	0	0.26	0.74	0.00
Warning signs U_{54}	0.11	0.89	0.00	0.00

4. Conclusion

From the perspective of agricultural machinery safety management, this paper selects 18 index from five aspects to build a comprehensive evaluation index system of agricultural machinery safety management. The system contains rich information, which fully reflects the industry management of agricultural machinery safety management, the basic situation of agricultural machinery drivers, the basic situation of agricultural machinery management, the coverage of agricultural machinery insurance and the working environment, The membership function of influencing factors of agricultural machinery safety management is established, and the fuzzy comprehensive evaluation method of agricultural machinery safety management is put forward. Taking the survey and monitoring data of agricultural machinery safety management in Liaoning Province as an example, the comprehensive evaluation results are in line with the actual situation, which verifies that the comprehensive evaluation method proposed in this paper is scientific and reasonable. This paper realizes the scientific evaluation of agricultural machinery safety management, which can provide reference for the evaluation of agricultural machinery safety management.

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