Application of Methods for Solving Multi-Criteria Problems when Choosing Precision Seeders

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Abstract. This article presents the process of choosing a precise seeding drill model using the methods of hierarchy analysis and generalized estimation. The results of the analysis represent preferred alternatives and recommendations for decision-making. The importance of the role of experts and their subjective opinions when using these methods is also emphasized.

1 The purpose of the study

The purpose of this study was to choose the optimal model of a precision seeding drill based on the analysis of hierarchies and the method of generalized evaluation. The study is aimed at determining the best alternative, taking into account the technical characteristics and performance criteria. The main goal was to simplify the process of selecting a seed unit and ensure optimal results based on seven main criteria, including reliability indicators.

2 Materials and methods

The article is based on the application of methods of generalized analysis and the method of hierarchy analysis, as well as on the analysis of data from the test results of seeders. Methods of generalized analysis and hierarchy analysis have been applied for systematic and comprehensive research and evaluation of precision seeders.

3 Results and discussion

To date, the Russian agricultural machinery market offers a wide selection of precision seeders produced by both domestic and foreign manufacturers. Taking into account such a variety of choices, making a decision about buying a specific model of a seeder becomes a difficult task that requires careful analysis. The purpose of the article is to choose the optimal model of the seeder, which will have the necessary technical characteristics and demonstrate high operational efficiency.

For effective decision-making in this area, methods of generalized evaluation and methods of hierarchy analysis are often used. Using the example of rowed seeders, you can

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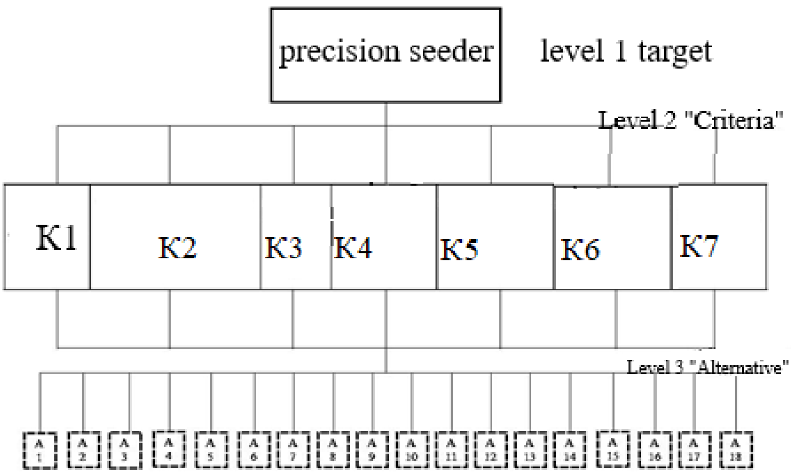
apply this method, which will allow taking into account various aspects and criteria when choosing the optimal model. It will help to make an informed choice, maximizing the benefits of the purchase and minimizing the possible negative consequences of the decision.

The method of hierarchy analysis (MHA) was used to conduct the study, as it is an effective method of evaluating product quality based on pairwise comparison of alternatives [4]. In accordance with the MHA plan, we conducted

a decomposition and presented the task in a hierarchical form. We evaluated precision seeders according to 7 criteria (level 2) and had 18 alternatives (see Table 1) (Figure 1).



K1 - operating speed, km/h , K2 - productivity per hour of main time, ha/h per 1 m of working width, K3- seeding depth, mm, (RMS), K4- number of seeds planted at a given depth ±1 cm, % , K5- Distribution of plants in a row (RMS) , K6- distribution of plants in a row (coefficient of variation), % , K7- time to failure, h , A1 – Pneumatic seed drill «MASKAR Maxi»; A2 – Seeder row MC-8; A3 – Seeder row Gaspardo SP 8 Dorada; A4 - Precision seeding drill Gaspardo MT8-70 (disk); A5 – Precision Seeding Drill Gaspardo SP Dorada MT8-70 (disk); A6 – Precision Seeding Drill Gaspardo SP 8 Dorada 8F-70; A7 Universal pneumatic seeder UPC-8-02; A8 – Pneumatic seeder «MASKAR Maxi»; A9 – Universal pneumatic seeder for precise seeding «Ferabox Futura 8»; A10 – Trailed pneumatic seeder for row crops Challenger CH 8108; A11 – The seeder is rowed block-compounded MC-8; A12 – Precision seeder for row crops SPP-8FS; A13 – Precision seeder for row crops SPP-8; A14 – Seeder for precise sowing TC-M 8000A; A15 – Seeder row Tempo TPF-8; A16 – Seeder row CM-12; A17 – Seeder for precise sowing «KINZE 3600»; A18 – Seeder for precise sowing John Deere DB-55.

Fig 1. Hierarchy diagram for solving the problem of choosing a seeder

To determine the importance of quality criteria, it is necessary to make a matrix of pairwise comparison (see Table 1). The weights of each element in the matrix are determined based on the subjective opinions of experts. The hierarchy analysis method (MHA) uses a scale of relative importance, which allows conducting a subjective comparison of various alternatives (see Table 1) [4,5].

It should be noted that the process of pairwise comparison is carried out according to the principle of the relative importance of the left elements of the matrix in comparison with the elements above. This allows establishing a hierarchical structure and determining the weight coefficients for each criterion.

However, when conducting pairwise comparisons, a subjective factor may arise related to the individual preferences of experts. To take this aspect into account, it is necessary to use methodological approaches, including conducting several rounds of expert assessments and calculating the consistency of their responses.

In addition, it is important to take into account the context and objectives of the assessment. In the case of precision seeders, it is necessary to establish which criteria are most important for a particular farm or producer, based on their specific needs and conditions.

In general, MHA provides a systematic and objective approach to comparing alternatives and determining the weight of criteria, which helps making a more informed decision when choosing a precise seeder.

Table 1. Relative importance scale

Intensity of relative importance	Definition	Explanation
1	Equal importance	Equal contribution of two activities to the goal
3	Moderate superiority of one over the other	Experience and judgment give an easy superiority of one type of activity over another
5	Substantial or strong superiority	Experience and judgment give a strong superiority of one type of activity over another
7	Significant superiority	One type of activity is given such a strong superiority that it becomes practically significant
9	Very strong superiority	The evidence of the superiority of one type of activity over another is confirmed most strongly
2,4,6,8	Intermediate solutions between two neighboring judgments	Accepted in a compromise case

The main purpose of compiling such a matrix is to identify the factors that are of the greatest importance in order to focus attention on them when solving a problem.

Table 2. is a matrix of paired comparisons of quality indicators based on subjective judgments

	К1	**К2**	**К3**	**К4**	**К5**	**К6**	**К7**
К1	1/1	2/3	1/2	2/5	2/7	1/3	2/1
К2	3/2	1/1	3/4	3/5	3/7	1/2	3/1
К3	2/1	4/3	1/1	4/5	4/7	2/3	4/1
К4	5/2	5/3	5/4	1/1	5/7	5/6	5/1
К5	7/2	7/3	7/4	7/5	1/1	7/6	7/1
К6	3/1	2/1	3/2	6/5	6/7	1/1	6/1
К7	1/2	1/3	1/4	1/5	1/7	1/6	1/1

We have also compiled similar matrices for the third level related to the criteria of the second level. Table 3 shows the values of the initial indicators that were actually used to compare seeders using the hierarchy analysis method (MHA) [4].

Table 3. Values of indicators for various alternatives [4]

Parameters	Alternatives																	
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
K1	7,92	9,01	8,7	8,23	8,09	7,75	6,75	6,96	7,8	11,59	8,9	11,8	8,1	11,2	13,9	9	8,4	9,5
K2	4,43	5,04	4,9	4,61	4,53	4,34	3,78	3,9	4,37	6,49	4,98	6,6	4,54	6,3	7,76	7,56	9,41	16
K3	3,7	14,2	3,6	4,1	4,1	6,2	1,2	7,9	4,6	3,9	0,4	5,3	8	3,9	7	16,9	4,5	7,1
K4	96	81,7	100	96	96	95,5	100	96	95	92	100	100	100	91,3	95,4	79,7	100	93
K5	н-д	н-д	2,9	2,3	2,3	17,4	9,4	17,2	9,8	2,7	1,3	1,7	2,1	12,4	н-д	25,4	11,8	12,4
K6	н-д	н-д	17,7	8	8	54,7	61,4	55,19	41,3	8,4	9,3	11,1	12,3	47	н-д	49,9	63,5	47
K7	75	37	73	39	81	75	75	82	75	36,5	37	61	72	72	83	24	70	70

After that, based on a group of paired comparison matrices, a set of local priorities is created that reflect the mutual influence of elements on elements located higher on the hierarchical level. [article 8]

Priority vectors are also calculated for the matrix of paired comparisons of quality indicators based on subjective judgments (Table 5).

Table 4. Priority vectors for the third level (Figure 1)

	Parameters						
Alternatives	K1	K2	K3	K4	K5	K6	K7
A1	0,049	0,041	0,045	0,056	0,044	0,044	0,065
A2	0,055	0,047	0,013	0,048	0,044	0,044	0,034
A3	0,053	0,045	0,046	0,058	0,069	0,060	0,064
A4	0,051	0,043	0,041	0,056	0,083	0,112	0,035
A5	0,050	0,042	0,041	0,056	0,083	0,112	0,070
A6	0,048	0,041	0,027	0,056	0,017	0,025	0,065
A7	0,042	0,036	0,130	0,058	0,028	0,023	0,065
A8	0,043	0,037	0,022	0,056	0,017	0,025	0,071
A9	0,048	0,041	0,036	0,056	0,027	0,031	0,065
A10	0,070	0,059	0,043	0,054	0,073	0,108	0,033
A11	0,055	0,046	0,366	0,058	0,129	0,099	0,034
A12	0,071	0,060	0,032	0,058	0,105	0,087	0,054
A13	0,050	0,042	0,022	0,058	0,089	0,080	0,063
A14	0,068	0,058	0,043	0,054	0,085	0,028	0,063
A15	0,083	0,070	0,024	0,056	0,044	0,044	0,072
A16	0,055	0,068	0,011	0,047	0,014	0,027	0,022
A17	0,052	0,084	0,037	0,058	0,026	0,022	0,061
A18	0,058	0,139	0,024	0,055	0,025	0,028	0,061

Table 5. Priority vectors for a matrix of paired comparisons of quality indicators based on subjective judgments

	Priority vector
Working speed, km/h	0,071
Productivity per hour of the main time, ha/h per 1 m of the width of the grip	0,107
Seed depth, mm: standard deviation, mm	0,143
The number of seeds planted to a given depth = 1 cm, %	0,179
Distribution of plants in a row: standard deviation, +-	0,250
Distribution of plants in a row: coefficient of variation, %	0,214
Time to failure, total, h	0,036

Based on the data presented in tables 4 and 5, global priorities are calculated (Table 6). The total value of a variant is defined as a weighted sum of local priorities, which is formed by additive combining priorities at all levels of the hierarchy [4,5].

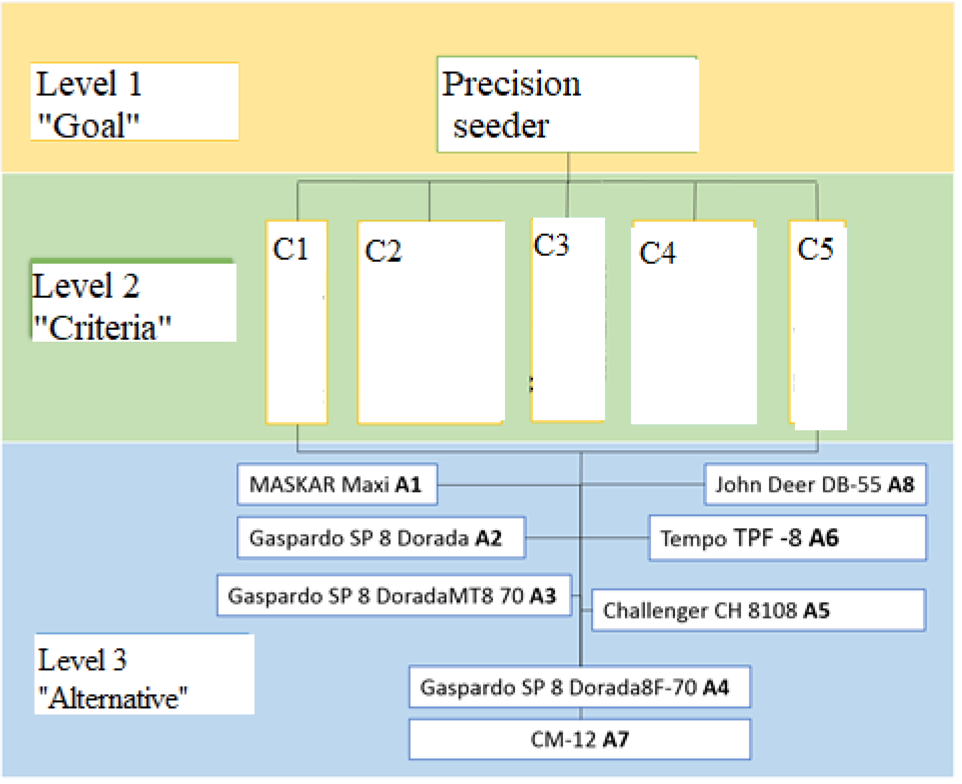
Table 6. Meaning of global priorities

Alternatives	**A11**	**A12**	**A5**	**A4**	**A10**	**A13**	**A3**	**A14**	**A15**
Global priorities	0,107	0,026	0,03	0,025	0,025	0,025	0,031	0,029	0,026
Alternatives	**A7**	**A1**	**A18**	**A17**	**A2**	**A9**	**A6**	**A8**	**A16**
Global priorities	0,052	0,031	0,025	0,028	0,017	0,028	0,026	0,026	0,014

As a result of the application of the hierarchy analysis method, it was found that alternative No. 11, namely the rowed block-compounded seeder MS–8 manufactured by JSC Millerovo - Selmash from the city of Millerovo, is the best choice among the alternatives considered. The use of this method significantly simplified the process of selecting a seed unit, taking into account seven main criteria, including reliability indicators [6,7].

Also, using the generalized evaluation method, we will analyze the seeders.

At the first stage of this method, we present a precision seeding drill as a technical system in the form of a hierarchy scheme (Figure 2).



Criterion 1 - operating speed, measured in km/h;
Criterion 2 - productivity for 1 h of the main time, measured in ha/h per 1 m of the width of the grip;
Criterion 3 - seeding rate, measured in thousands of pieces / p.m;
Criterion 4 - percentage of seeds planted to a given depth ± 1 cm;
Criterion 5 - time to failure, total, measured in hours.

Fig 2. Diagram of the hierarchy of characteristics of rowed seeders

The measurement limits of each of these criteria are determined by various factors:

- technical characteristics of the tractor and the conditions of sowing;
- value of the working speed and the width of the seeding machine;
- variety of seedlings, soil and climatic conditions and the tasks set for agronomists;
- settings of the seeder and its design features;
- level of reliability conceived during design, production and operation.
- taking into account all these factors makes it possible to determine the boundaries of measurements and evaluate the effectiveness of each type of tilled seeder according to the above criteria.

Table 7. The value of indexes

№	Title of the criterion	NAP	Limits of changing criteria		The value of the parameters							
					$Alternative\ x_p^i$							
			x_{imin}	x_{imax}	A1	A2	A3	A4	A5	A6	A7	A8
1	Cr 1	1	5,4	14,5	7,92	8,7	8,23	7,75	11,59	13,9	9,0	9,5
2	Cr 2	1	3	18	4,43	4,9	4,61	4,34	6,49	7,76	7,56	16,0
3	Cr 3	0	3	7	4	6	4	4	4	4	4	4
4	Cr 4	1	70	110	96	100	96	95,5	92	95,4	79,7	93
5	Cr 5	1	20	100	78	75	39	75	36,5	85	24	70

Here the concept of NAP is used to describe the impact of criteria on the result. A value of 1 indicates a direct relationship, that is, with an increase in the value of the factor, efficiency also increases, while a value of 0 indicates an inverse relationship, where an increase in the value of the factor leads to a decrease in efficiency.

To reconcile the actual numerical values of the factors with the numerical values of the scale, we introduce a scale factor (Mi), which is calculated using the formula (2). Given the maximum and minimum levels of efficiency (desired levels) dmax=0.80 and dmin=0.20, the X values corresponding to these boundaries can be determined using the formula (1).

$$X_A = X_{\min} = 4 + [-\ln(-\ln d_{\min})] = 3{,}53$$
$$X_B = X_{\max} = 4 + [-\ln(-\ln d_{\max})] = 5{,}50 \quad (1)$$

$$M_i = \frac{x_{imax} - x_{imin}}{X_B - X_A} \quad 2)$$

it is necessary to translate the natural (real) values of the factors into dimensionless ones.

At **NAP**=1 then $x_i = X_A + \frac{x_i^p - x_{min}}{M_i}$ (3)

If (**NAP**=0) then $x_i = X_B + \frac{x_i^p - x_{min}}{M_i}$ (4)

where x_i – code value of the factor

x_p^i – natural value of the factor.

To determine the particular desirability functions, we use formula (5) and substitute the values of xi (5). This allows us to obtain the value of the desirability coefficient (or preference) di for each alternative according to five criteria.

$$d_i = e^{-e^{4-x_i}} \quad (5)$$

After the real numerical values of the factors x_i^p are matched to the partial undesirability functions (you), it is possible to determine the generalized indicator B. The generalized indicator is determined by the formula (6):

$$D = \sqrt[n]{\prod_{i=1}^{n} d_i} \quad (6)$$

where n – amount of criteria.

The exponent D is defined as the geometric mean of the partial coefficients d_i.

The calculation results are presented in Table 2.

Table 8. Results of calculation of the generalized criterion for eight alternatives

Designation	Alternative 1				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_1	1,83	3,71	2,03	12,69	45,69
x_1	4,91	4,54	5,01	4,04	4,80
d_1	0,67	0,56	0,69	0,51	0,64
D_1	0,502				
Designation	Alternative 2				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_2	1,83	3,71	2,03	12,69	45,69
x_2	5,34	4,66	4,02	4,71	4,73
d_2	0,77	0,60	0,38	0,61	0,62
D_2	0,469				
Designation	Alternative 3				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_3	1,83	3,71	2,03	12,69	45,69
x_3	5,08	4,59	5,01	4,40	3,95
d_3	0,71	0,57	0,69	0,51	0,35
D_3	0,452				
Designation	Alternative 4				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_4	1,83	3,71	2,03	12,69	45,69
x_4	4,82	4,51	5,01	4,36	4,73
d_4	0,64	0,55	0,69	0,50	0,62
D_4	0,493				
Designation	Alternative 5				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_5	1,83	3,71	2,03	12,69	45,69
x_5	6,92	5,09	5,01	4,08	3,89
d_5	0,95	0,72	0,69	0,40	0,33
D_5	0,506				
Designation	Alternative 6				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_6	1,83	3,71	2,03	12,69	45,69
x_6	8,18	5,44	5,01	4,35	4,95
d_6	0,98	0,79	0,69	0,49	0,68
D_6	0,637				
Designation	Alternative 7				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_7	1,83	3,71	2,03	12,69	45,69
x_7	5,50	5,38	5,01	3,11	3,62
d_7	0,80	0,78	0,69	0,09	0,23
D_7	0,413				
Designation	Alternative 8				
	Cr 1	Cr 2	Cr 3	Cr 4	K 5
M_8	1,83	3,71	2,03	12,69	45,69
x_8	5,77	7,66	5,01	4,16	4,62
d_8	0,84	0,97	0,69	0,43	0,59
D_8	0,632				

Thus, based on the initial data presented in Table 2, we get the following results: D6 = 0.637 > D8 = 0.632 > D5 = 0.506 > D1 = 0.502 > D4 = 0.493 > D2 = 0.469 > D3 = 0.452 > D7 = 0.413. This means that we choose the alternative with the highest value.

The generalized evaluation method allows choosing the Tempo TPF-8 precision seeding drill model as the preferred one based on the criteria of technical characteristics. However, in the absence of this model, you can use the sequence of preferred alternatives that we have received.

The generalized evaluation method and the hierarchy analysis method are two effective approaches for making decisions when choosing a seed unit based on various criteria, including reliability indicators [8,9].

Using the hierarchy analysis method, the preferred alternative for choosing a seed unit was determined. Based on seven main criteria, including technical characteristics, the Tempo TPF-8 precision seeder model was selected. This choice is based on the weights of the elements, which are determined based on the subjective opinion of experts.

However, in the absence of the Tempo TPF-8 model, it is possible to turn to the generalized evaluation method, which also makes it possible to simplify the selection of the sowing unit based on the criteria considered. The generalized estimation method takes into account the numerical values of factors and partial desirability functions, allowing us to determine a generalized indicator D for each alternative.

Conclusions: thus, both methods provide valuable tools for decision-making when choosing a seed unit. The hierarchy analysis method relies on expert opinion and allows you to determine the preferred alternative based on the weights of elements expressing relative importance. At the same time, the generalized estimation method takes into account the numerical values of the factors and allows comparing alternatives based on the generalized indicator D.

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