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Feasibility study for choosing the best combine harvester design

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Abstract. A modernized Harrington function with three zones of evaluation indicators is proposed: excellent-good-satisfactory for making a decision on choosing the best design of a combine harvester. Harrington's desirability function is used only in the 0.2 ... 0.8 section, in the interval of which the system of j-th estimated indicators with its own units of measurement (operating costs, grain losses, labor costs, energy consumption of the combine harvesting process) is located. The developed desirability scales were used based on economic tests of combines. Dependences are obtained for converting the values of experimental estimated indicators to a dimensionless scale limited by the range of the desirability function 0.2 ... 0.8. By the method of paired comparison of the estimated indicators, their rank place, the weight coefficient of each indicator used in calculating the generalized criterion for the comprehensive assessment of each combine harvester was determined. The maximum value of the criterion determines the best design of the combine from the alternative. The values of the D_i^k criteria for the integrated assessment of combines with and without weight factors (mean geometric value of the criteria) have been analysed. When using the latter, a more significant difference was obtained between the compared designs of combines. Such a comparison can be applied to carry out comparative tests of combines under the same conditions (yield, moisture, weediness, etc.). The purpose of the work is to substantiate, using the example of a group of compared grain harvesters, the best design option using the proposed system of evaluation indicators and generalized criteria for complex evaluation.

1. Introduction

Combine harvesting of grain crops is currently the main method and is performed by self-propelled combine harvesters. They differ in their design features. They determine the quality of the machine, their productivity, efficiency, grain loss. The consumer tries to choose the best design that matches his capabilities, providing the required cleaning quality and economy. These are the main estimates that are taken into account when choosing the best option for practical use. As a rule, these are operating costs, grain losses, labor costs and the energy intensity of the machine's operation process. As a rule, the consumer purchases combines with low costs, high productivity (low labor costs) and low energy consumption. In this case, the yield losses allowed for agrotechnical requirements are taken into account.

Production tests [1] have yielded machine results that depend on operating conditions. Thus, estimated indicators have been determined that can be compared provided that a number of identical conditions are observed: yield, soil and grain moisture, weediness, lodging of crops, simultaneous ripening in one field, etc.

An important role is played by equipping combines with means of automatic control and adjustment of operating modes, equipment that improves the working conditions of the operator. It is also very important when harvesting to achieve strict compliance with yield, threshing capacity, header width and working speed. Underloading or overloading the thresher is fraught with grain losses, irrational engine loading and excessive fuel consumption. All this affects the economic efficiency of the combine.

The scientifically grounded choice of the best design of the combine harvester from the alternative should be determined by calculation using a system of evaluation indicators.

2. Materials and methods

In preparing the article, we used generalization methods [2], the results of production tests of grain harvesters [3] in agricultural enterprises of the Krasnodar Territory, as well as the results of our own research [4, 5]. As a criterion for evaluating the best version of a combine harvester, a generalized criterion for an integrated assessment was adopted, calculated using the Harrington functions [6]:

$$D_i = \sqrt[n]{\prod_1^n d_{ij}^{k_j}} \to 1.0, \tag{1}$$

where D_i is a generalized indicator of the complex assessment of the i-th machine;

d_{ij} is the desirability of each j-th estimated indicator of the j-th i-th machine;

n is the number of studied i-th machines;

k_j is the weighting coefficient of each j-th estimated indicator.

Table 1 shows the brands of the studied i-th combines, the system of the j-th estimated quality indicators obtained on the basis of their production tests [2] and generalized criteria for complex assessment with taking into account the weight coefficients D_i^k and without them D_i.

Modernization of the Harrington function [6] consists in its mathematical expression (2) and graphical representation (figure 1):

$$d(y') = e^{-e^{-(y'-2)}}, \tag{2}$$

where $d(y')$ is the desirability function of each j-th estimated indicator, converted to a dimensionless scale y' from the system of scales (A) with natural values of these indicators.

All estimated indicators are limited on their scales (A) by the segment BC (figure 1), which in turn is limited by the values of the desirability function $d(y')$ in the range 0.2 ... 0.8, projected on the y' axis. Point B of the segment BC characterizes the minimum values of each j-th indicator and point C - the maximum.

The natural values of the j-th estimated indicators of the A scale are converted to a dimensionless scale y' according to the conversion formulas (3 ... 6) to calculate desirability function $d(y')$:

- for operating costs U:

$$y_1' = -0.0086 j_1 + 6.22, \tag{3}$$

- for grain losses P:

$$y_2' = -0.894 j_2 + 4.16, \tag{4}$$

-for labor costs Z_t:

$$y_3' = -32.73 j_3 + 4.62, \tag{5}$$

- for energy intensity E:

$$y_4' = -0.0837 j_4 + 6.89, \tag{6}$$

Thus, all values of the j-th estimated indicators with units of measurements on the family of scales A (figure 1) are converted using the straight line BC to the scale y' in the interval 1.524 ... 3.5 (figure 1) and further to the Harrington desirability curve $d(y')$ according to the calculation formulas (3…6).

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The generalized criterion for the complex assessment of the i-th combine is determined by expression (1) taking into account the weight coefficient k_j. Estimate indicators of combine harvesters are given in tables 1 and 2.

Table 1. Estimate j-th indicators of the studied combine harvesters.

i-th version of the combine	Model of the i-th beet harvester	Engine power	j-th estimate indicators			
			operating costs U, rub / t	root damage P,%	labor costs Zt, man-h / t	energy intensity M, MJ / t
1	Vektor -410	154	519	1.89	0.094	52.2
2	Acros-530	184	543	2.24	0.061	40.6
3	TORUM-740	294	387	1.85	0.06	64.2
4	Polesie-GS12	242	426	2.22	0.059	50.9
5	John Deere-S690	390	452	2.93	0.034	48.1
6	Massey Ferguson 9790	257	547	2.95	0.061	56.5
7	LEXION-560	283	462	1.55	0.048	48.3
8	LAVERDA-306	224	502	0.74	0.054	43.6
	Weight coefficient Kj		0.333	0.183	0.3	0.184

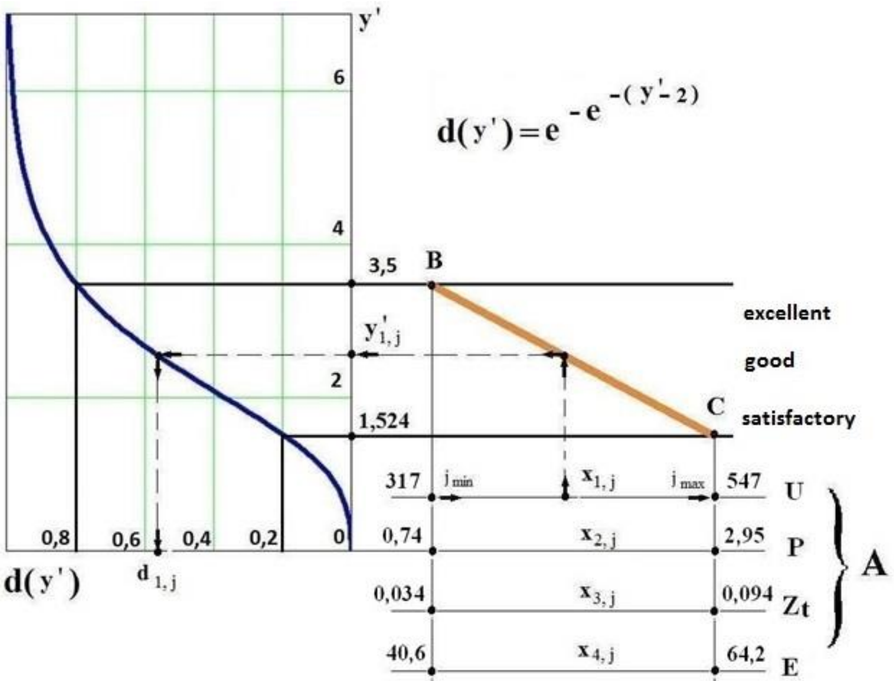

Figure 1. Modernized d-Harrington desirability function, scale (A) of estimate j-th indicators and dimensionless scale y' function.

j_1 – operating costs U, rub./t; j_2 – loss of grain P, as a percentage of the yield; j_3 – labor costs Z_t, man-h / t; j_4 – energy consumption E of the combine harvester operation process, mJ / t.

After finding the desirability functions $d(y')$ we calculate the generalized criterion D_i (1).

3. Discussion and results

The results of the analysis of the quality of the compared i-th combines are presented in tables 1 and 2. Domestic (Vector -410, Acros 530, TORUM 740) and foreign combines (John Deere 5690, Polesie GS12, Massey Fergusson 9790, Lexion 560, Laverda 306).

Combines differ in engine power, nominal output (tonnes of grain per hour) and design features. The level of training of operators is high.

Comparison of combines was made according to the j-th estimate indicators (table1): operating costs (rubles / hectare), grain losses (as a percentage of the harvest), labor costs (people per hour / ha) and the energy consumption of the combine operation process (MJ / hectare). After constructing the scales (A) of the estimated indicators, translating them into a segment (BC) and a scale y_1' we determine the desirability function of each j-th indicator (table 2).

Table 2. Desirability function of j-th estimate indicators of combine harvesters.

	Model of the i-th combine	The desirability function of the j-th estimate indicators				Generalized criterion for comprehensive assessment	
		operating costs U, rub / t	root damage P,%	labor costs Zt, man-h / t	energy intensity M, MJ / t	D_i^k	D_i
1	Vector -410	0.28	0.54	0.20	0.56	0.75	0.36
2	Acros-530	0.21	0.43	0.58	0.80	0.80	0.45
3	TORUM-740	0.67	0.55	0.59	0.20	0.84	0.46
4	Polesie-GS12	0.57	0.43	0.60	0.59	0.86	0.54
5	John Deere-S690	0.49	0.21	0.80	0.66	0.85	0.48
6	Massey Ferguson 9790	0.20	0.21	0.58	0.43	0.75	0.32
7	LEXION-560	0.46	0.63	0.70	0.65	0.88	0.60
8	LAVERDA-306	0.34	0.80	0.65	0.75	0.86	0.59

As follows from the data in table 2, the best (maximum) value of the desirability function for one indicator takes place only for one brand of combine harvesters: for operating costs (0.67) - TORUM-740 combine, for grain losses (0.8) - Laverda, for labor costs (0.8) - John Deere, by energy intensity (0.8) - Acros-530. At the same time, low desirability (0.2 ... 0.28) in terms of operating costs is observed in three brands of combine harvesters - Vector, Acros and Massey Ferguson.

The Laverda harvester has the best desirability in terms of grain losses (0.8), and the worst in its working conditions - John Deere and Massey Ferguson. In terms of labor costs, John Deere has the best desirability, and in terms of energy intensity - Across.

It should be noted that at this stage it is impossible to draw final conclusions about the results of combine harvesters operation, since they were tested in fields with different yields and the state of the grain mass, but the method of evaluating combines using the modernized Harrington function can be used [7, 8, 9].

The generalized criterion D_i for the complex evaluation of combines was calculated using the developed computer program using formula (1) taking into account the coefficients the weight of the k_j j-th estimate indicators (table 1) or without them. The values of the D_i criteria for each brand of the i-th combine are given in table 3.

Table 3. Generalized criteria for the comprehensive assessment of the i-th combine harvesters.

Number of the i-th combine	The brands of the compared i-th cars combine	Generalized estimates		Subject to rounding
		without weightage, D_i	taking into account the weightage, D_i^k	

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1	Vector-410	0.360	0.754	0.8
2	Acros-530	0.452	0.803	0.8
3	TORUM-740	0.456	0.840	0.8
4	Polesie -GS12	0.544	0.863	0.9
5	John Deere-S690	0.480	0.846	0.9
6	Massey Ferguson 9790	0.316	0.750	0.8
7	LEXION-560	0.604	0.877	0.9
8	LAVERDA-306	0.591	0.859	0.9

Judging by the data in table 3, the LEXION-560 combine has the highest value of the generalized criterion for complex assessment, both without taking into account the weight coefficient of the estimate j-th indicators D_i, and with it D_i^k, is the LEXION-560 combine, respectively, 0.604 and 0.877. According to the calculation results for D_i the LEXION-560 combine provided low grain loss (1.55%), low labor costs (0.048 man-hour / ton) and low energy consumption of the harvesting process (48.3 MJ / t) due to the price of the machine. The LAVERDA-306 combine came close to the LEXION-560 in terms of grain losses, which were two times lower than that of the LEXION-560. With the same yield losses, LAVERDA lagged behind the LEXION significantly higher in terms of criteria D_i and D_i^k. Below its capabilities, the D_i value was obtained for Jhon Deere and Massey Ferguson 9790 combines due to the high price of the combine and grain losses (2.95%) under test conditions. A low value of the coefficients D_i and D_i^k occurs for the Vector-410 and Acros-530 combines due to the high price and grain losses that exceed the agrotechnical requirements [10].

Of interest is the influence of the weight coefficients of the j-th estimate indicators on the result of calculating the criterion for the integrated assessment D_i^k of the combine. If the values obtained during the tests are rounded to one decimal place (table 3), then the maximum difference between them will be no more than 10 percent. None of the studied combines has a clear advantage. As a result of calculations according to the D_i criterion, without taking into account the weight of the estimated indicators, significant preference is given to the LEXION-560 combine (table 3). The generalized criterion for a comprehensive assessment is influenced by: a wide variety of harvesting conditions, the parameters of the compared combines, weight factors. These factors equalize its absolute value, which tends to unity. The geometric mean value of the generalized criterion for complex assessment for making a decision on the best option from the compared machines is calculated without taking into account the weight coefficients of the j-th estimated indicators. In this case, compared machines must be tested under the same conditions.

4. Conclusion

The proposed assessment method allows an objective approach to the solution of the problem of choosing the best design of a combine harvester when using the modernized Harrington function in the range of desirability of the j-th estimated indicators 0.2 ... 0.8. Four estimated indicators of the results of the work of combines with their own scales of permissible values of these indicators were revealed when testing the combines. The dependences of the conversion of the natural values of the selected assessment indicators into dimensionless ones on the y', scale, used to calculate the desirability function in dimensionless quantities and the generalized criterion for complex assessment, have been determined. A necessary condition for an objective assessment of the quality of compared machines is the same test conditions (yield, moisture, etc.). The calculation of the generalized assessment criterion was carried out taking into account the weight coefficient of the j-th estimated indicators and without it, since in some cases these coefficients smooth out the significance of the differences between the options.

References

[1] Gritsyn V Yu, Benov V E, Shirokikh A P *et al.* 1994 *The Concept of Development of*

IOP Conf. Series: Earth and Environmental Science **848** (2021) 012166 doi:10.1088/1755-1315/848/1/012166

Mechanization of Harvesting Grain Crops for the Period up to 2005 (Moscow)
[2] Tsybulevsky V V and Maslov G G 2021 Decision theory for choosing the best machine from alternative options *IOP Conf. Ser.: Earth and Environmental Sci.* **677** (2021) 032097
[3] Tabashnikov A T, Kovlyagin F V *et al.* 2009 *Guidelines for the Selection of Competitive Combine Harvesters for Agricultural Producers of the Krasnodar Territory* (Novokubansk: FSEI "Rossinformagrotech")
[4] Maslov G G, Trubilin E I, Yudina E M and Rinas N A 2018 Concept of creating energy – resource – saving technologies for harvesting grain with multifunctional aggregates *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **9 (4)** 623-30
[5] Maslov G G, Palapin A V and Rinas N A 2014 *Multifunctional harvesting unit International Agricultural Journal* **1-2** 16-19
[6] Harrington E 1965 The desirability function *Industrial Quality Control* **21(10)**
[7] Chernoivanov V I, Severny A E, Khalfin M A *et al.* 2002 *Resource Saving in the Technical Operation of Agricultural Machinery* (Moscow: GOSNITI - FSEI "Rosinformagrotech") **part I, II** p 3
[8] Kormanovsky L P 1999 Energy saving is the top priority in the coming century *Agricultural Machinery* **4** 3-6
[9] Zhalnin E V 2020 Ways to revive the combine park *Selskiy Mechanizator* **10** 6-7
[10] Elizarov V P et al. 2005 *Initial Requirements for Basic Machine Technological Operations in Crop Production* (Moscow: Ministry of Agriculture of the Russian Federation, Federal Agency for Agriculture)