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PURCHASE OF HIGH POWER AGRICULTURAL TRACTORS ON THE BASE OF TECHNICAL AND ECONOMIC PARAMETERS' ANALYSIS

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The paper presents the analysis of possibilities of selection and purchase of high power agricultural tractors for farms. The presented method, based on technical and economical parameters, allows to select the tractor from a group consisted of tractors with similar technical parameters and enables to make potential decision of buying.

Introduction. Taking the decision on the purchase of an agricultural machine for farm's needs is one of the most responsible phases of a complex process of machines' selection for a farm. The basic work in this phase is made by a purchaser, who should use all accessible information gathered during the stages: evaluation of necessity of a machine's purchase for a farm, choice of a machine with appropriate technical and operational parameters, selection of a particular type and producing company form the whole range of machines, which fit the purchaser's requirements.

In the real situations connected with the choice and purchase of agricultural machines, during the phase of selection of a specific type and brand, a purchaser does not have appropriate set of information enabling to clear choice of a particular machine. That is why the rule of shorteningg of the least advantageous decisions can be used, which leads to gradual elimination of preliminary assumed and possible decisions. In this study the analysis of technical and economic factors of high power agricultural tractors was presented, which enables to make the optimal choice and possible purchase of these tractor for farms.

Description of the method. Three stages of reaching the final solution can be distinguished in the process of selection and purchase of agricultural tractors for farms. During the first phase we eliminate the last advantageous decisions from the set of all possible decisions Y, which narrows this set to the set of decisions possible to accept (admissible) $Yd \subseteq Y$. The sign $\subseteq$means that the set of admissible decisions Yd is the subset of all possible decisions Y, in some cases it can be the same. On the second stage, the set of admissible decisions is limited to the set of efficient decisions $Ye \subseteq Yd$ through elimination of less advantageous decisions. During the last phase we determine the final (optimal) decisions Y* from the set of efficient decisions. This procedure can be noted with the following signs: By where Y – set of all possible decisions, Yd – set of admissible decisions, Ye – set of efficient decisions, Y* – final decision.

The total number of decisions possible to accept are limited to a level of admissible decisions on the base of analysis of fundamental restrictions. Admissible decisions fulfill basic restrictions, for example these will be tractors with appropriate engine power for cooperation with machine of particular efficiency, which will be able to make the planned work in a suitable time. Procedure of reaching the subset of admissible decisions from the whole set of possible decisions can run through logical thought analysis or formally, with use of particular calculations enabling to determine necessary parameters of a tractor. In practice, the process of narrowing of the total number of decisions to admissible ones takes place even on the stage of preliminary decisions' formulation so preliminary number of accepted decisions can be perceived as a set of admissible decisions.

Following particular procedure based on gradual elimination of less advantageous decisions is a condition of final choice of the decision because the final decision Y* is included into the set of decisions possible to accept. That is why in order to look for the final decision, only the set of admissible decisions should be analyzed. Narrowing of the set of admissible decisions to the set of efficient decisions is made on the base of expectations' analysis. A decision can be called efficient if there is not any decision which is more efficient than this one. The set of efficient decisions is often called in literature as the Pareto's set or the set of non–dominating decisions. In the simplest case of one aim and one parameter, which characterizes this aim, the set of efficient decisions consists of one decision, which at the same time is the final (optimal) decision Y*. In cases, where there are a few aims and parameters according to which we compare them, the set of efficient decisions usually consists of more than one decision, and often includes a considerable part of the set of admissible decisions or even is the same. That is why it can be stated, that in extreme cases the achieving of the set of efficient decisions does not make smaller the set of admissible decisions. However, the set of efficient decisions is usually a part of the set of admissible decisions and consists of more than one of them. The rate of decreasing of a number of admissible decisions to the set of efficient decisions can be characterized by a coefficient of choice possibility γ

$$\gamma = \frac{m_d - m_e}{m_d - 1} \quad (1)$$

where: *md* – number of admissible decisions, *me* – number of efficient decisions.

There are a few methods, which can be used to determine the set of efficient decisions. They include for example: a method of direct comparing and a method of multicriteria choice. The method of direct comparing can be used in cases of small number of decisions and small number of parameters, which characterize them. If we have *md* of admissible decisions and q – number of parameters according to which we compare these decisions, so the number of required comparisons can be determined by the value *mq(mq – 1)q/2*.

The method of multicriteria comparisons is a very useful and handy method of determination of the set of efficient decisions from the set of admissible decisions. Let us assume, that there is the set of admissible decisions Yd = (Y1 Y2 . . . , Ym.) and a number of parameters characterizing these decisions y1, y2, . . . yq. As the parameters characterizing the choice of particular type and brand of an agricultural tractor can be: engine power, tractive power, coefficient weight/power, price and others. For each decision numbered with *i* we determine a vector of parameters' significance (yi1, yi2, . . . yiq). According to the Pareto's rule, one decision Yi is more appropriate than the next Yj, if a vector's condition "not worse" is fulfilled:

$$(yi1, yi2, \ldots yiq) \geq (yj1, yj2, \ldots yjq) \quad (2)$$

Fulfilling the vector's condition "not worse" means realizing an inequality:

$$\begin{gathered} yih \geq yjh \\ yil \geq yjl \quad (h \neq l,\ h,l = 1,2, \ldots q) \end{gathered} \quad (3)$$

Expression yih means the preference parameter with h number and the decision with i number.

The determination of the final decision is the last stage in the process of tractor's selection for a farm. All decisions in the set of efficient decisions are very similar so it is difficult to indicate which one is the optimal one. According to the presented features of the set of efficient decisions, the final (optimal) one should be found out in the set of these decisions. Any chosen decision from the set of efficient decisions is a non–dominating decision in comparison with this set, which means that it is not worse than anyone of the remaining ones. That is why, if there is not any possibilities to gain additional information enabling to determine the optimal decision from the set of efficient decisions, even with the use of additional resources and working time, a choice of any decisions from the set of efficient decisions should confirm a satisfactory effect resulting from the use of these tractors on a farm.

Additional information which allows to determine the optimal decision from the set of efficient ones can be achieved on the base of: – direct ordering of these decisions according to the forecasting work effects, – evaluation and ordering the efficient decisions according to the forecasting work effects by branch experts.

The most efficient solution allowing the determination of the final (optimal) decision can be an assumption on linearity of function of selection of the optimal decision (Jemielianow, 1976,Fon Nejman, 1979):

$$F(\alpha_{is}) = \sum_{s=1}^{q} K_s \alpha_{is}$$

where: αis – coefficient of efficiency of made decisions, *i* – number of a decision from the set of efficient decisions, *q* – number of evaluated parameters, n – number of an evaluated parameter, *Ks* – significance coefficient of particular parameter.

Efficiency coefficient of made decisions can be determined on the base of the following relationship:

$$\alpha_{is} = \sum_{j=1}^{d} f_{ij} \qquad (4)$$

If we know the value of significance coefficient of a particular parameter – *Ks,* we can determine the optimal decision on the base of the following relationship:

$$Y^* \Leftarrow \min_{i}^{n} \sum_{s=1}^{d} K_s \alpha_{is} \qquad (5)$$

where: i – number of decision from the set of efficient decisions.

Analysis results. There is an assumption for the purpose of this study: the selection and purchase concerns high power agricultural tractors, necessary to cooperation with high efficiency and power 150–170 kW. That is why from the whole range of agricultural tractors only high power agricultural tractors were chosen and they were included into the set of admissible decisions Yd.

Some parameters of high power agricultural tractors were taken to determine the subset of efficient decisions (table 1, in order to avoid the publishing of the company's name and tractor's type there were labeled with T letter, the company's name, which produces particular type of a tractor can be found through the contact with the author of this publication). The price of particular tractors was divided by a value of a parameter in order to get unit costs of these parameters. According to the author, only unit cost of a particular parameter can be an adequate measure of the possibility of purchase of a particular tractor. The values of parameters without reference to a tractor's price are not enough arguments because the cost of achieving them can be so high that it is not acceptable by farmers. Afterwards all of these parameters were ordered, giving the most advantageous one (the lowest unit cost) number 1 and accordingly the least advantageous the last number in an order. All the tractors and their lists are included into the table 2.

The whole set of admissible decisions were analyzed according to the formula nr 3 and after that according to the Pareto's rule an order of the subsets and individual decisions was determined.

$$(Y1, Y3, Y6) \geq (Y5, Y7) > Y2 > Y4 \quad (6)$$

The set consisted of three decisions Y1, Y3, Y6 can be selected as the set of efficient decisions (on the base of the formula nr 6).

Table 1

Specification of high power agricultural tractors and their technical parameters

Tractor	Nominal engine power kW	Coefficient weight/power kg/kW	Tractive power with nominal revolutions kW	Unit use of fuel with nominal revolutions g/kWh	Maximal tractive power kW	% of power on WOM with nominal revolutions	Hydraulic system, maximal power kW	Elevator, elevator's power in the low position daN	Noise in a closed cabin dB
T1	140,0	64,0	96,9	350,0	106,3	78,0	24,2	6900,0	74,0
T2	156,0	75,0	102,3	330,0	121,6	76,0	27,5	8103,4	77,0
T3	147,0	53,0	111,2	307,0	112,9	84,0	32,5	7398,5	78,0
T4	147,0	57,0	113,1	280,0	120,2	82,0	29,3	5949,6	78,5
T5	155,0	63,0	122,8	279,0	134,9	84,0	32,7	5903,0	77,0
T6	147,0	55,0	111,5	336,0	112,2	82,0	31,9	5651,1	79,5
T7	140,0	65,0	99,2	330,0	115,3	79,0	26,6	8030,0	74,0

Source: Own elaboration.

Table 2.

Specification of high power agricultural tractors and their technical parameters according to unit costs of

Tractor	Nominal engine power EUR/kW		Coefficient weight/power EURkW/kg		Tractive power with nominal revolutions EUR/ kW		Unit use of fuel with nominal revolutions EURkWh/g		Maximal tractive power EUR/kW		% of power on WOM with nominal revolutions		Hydraulic system, maximal power EUR/kW		Elevator, elevator's power in the low position EUR/daN		Noise in a closed a cabin EUR/dB	
	Value	Order	Value	Order	Value	Order	Value	Order	Value	Order	Value	Order	Value	Order	Value	Order	Value	Order
T1	768,3	**2**	1680,6	**1**	1110,0	**5**	307,3	**2**	1011,9	**3**	1379,0	**2**	4444,6	**5**	15,6	**1**	1453,5	**2**

Table 2continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
T2	886,1	**6**	1843,1	**3**	1351,3	**7**	418,9	**5**	1136,8	**6**	1818,9	**7**	5026,7	**7**	17,1	**3**	1795,3	**7**
T3	793,4	**3**	2200,7	**6**	1048,9	**2**	379,9	**4**	1033,1	**4**	1388,5	**3**	3588,8	**2**	15,8	**2**	1495,3	**3**
T4	945,2	**7**	2437,6	**7**	1228,5	**6**	496,2	**7**	1155,9	**7**	1694,4	**6**	4742,0	**6**	23,4	**7**	1769,9	**6**
T5	831,1	**5**	2044,8	**4**	1049,1	**3**	461,7	**6**	954,9	**2**	1533,6	**5**	3939,6	**4**	21,8	**6**	1673,0	**5**
T6	688,6	**1**	1840,4	**2**	907,8	**1**	301,3	**1**	902,1	**1**	1234,4	**1**	3173,1	**1**	17,9	**4**	1273,2	**1**
T7	862,3	**4**	1857,3	**5**	1217,0	**4**	365,8	**3**	1047,0	**5**	1528,1	**4**	4538,5	**3**	15,0	**5**	1631,4	**4**

Source: Own elaboration.

Table 3

Set of efficient decisions

Tractor	Nominal engine power kW	Coefficient weight/power kg/kW	Tractive power with nominal revolutions kW	Unit use of fuel with nominal revolutions g/kWh	Maximal tractive power kW	% of power on WOM with nominal revolutions	Hydraulic system, maximal power kW	Elevator, eleator's power in the low position daN	Noise in a closed a cabin dB	Value of selection function Y*
T1	2	1	5	2	3	2	5	1	2	**2,8**
Y3	3	6	2	4	4	3	2	2	3	**3,4**
Y6	1	2	1	1	1	1	1	4	1	**1,7**
Coefficient of parameter's significance Ks	0,10	0,10	0,11	0,16	0,13	0,10	0,10	0,10	0,1	

Source: Own elaboration.

It should be mentioned here that each of these decisions is non–dominating in comparison to the other two and any of them is not worse than Y5 and Y7 and is better than Y2 and Y4.

On the base of the formula nr 1 the coefficient of choice was possibility determined $\gamma = 0{,}67$.

The determination of the final (optimal) decision was run according to the formula nr 5. In order to realize this aim, the set of efficient decisions with characterizing parameters were gathered in the table 2. Significance coefficient Ks was determined for all parameters with the use of the expert method. The value of Ks coefficient for each parameter means the weight of this parameter in comparison with all the other parameters, the sum of coefficient for all parameters equals 1. Afterwards, according to the formula nr 5, the value of selection function was determined for each decision.

On the base of analysis of the value of selection function it can be stated that the decision Y6 is the optimal one (the lowest value of selection function). It is the decision on purchase of Massey Ferguson 810 tractor.

Conclusions. The method presented above allows the selection and possible purchase of these sources of energy for a farm, logically and economically proved, based on the analysis of technical and economic parameters of high power agricultural tractors,. On the basis of conducted analysis of accessible number of parameters in a particular group of tractors it can be stated that the most substantiated choice would be: Massey Ferguson 810, then Deutz–Fahr Agroton 200 and Case Magnum 7220.

It should be also mentioned here that in further researches there should be some additional operational parameters' influence taken into account, they are: proneness to breakdowns, average year costs of repairs and overhauls as well as replacements and operational materials for these tractors during their operational work, accessibility and efficiency of guaranteed repairs by a producer or distributor of these machines in Poland. As the result of lack of access to this kind of data it was not taken into account in this study but they will be a researches' subject for further analyses in the future.

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