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SELECTION AND HIERARCHIZATION OF THE AHP METHOD BASED DECISION PROCESS CRITERIA FOR THE CHOICE OF BATTERY FOR POWER DRIVEN AGRICULTURAL MACHINES

Summary

The lead-acid batteries are used in every power driven agricultural machines. Despite numerous faults (especially connected to the environmental protection aspects), the batteries have one basic advantage, i.e. low price. Their life is increasingly short and sometimes they require replacement after only 2-3 years of use. The correct exploitation of the battery depends mainly on the proper selection of wiring system units applied in an agricultural machine. The decision process related to the purchase of a proper battery is one of the most difficult and assumes most responsibility in terms of agricultural machines maintenance. The faulty selection of a battery may result in the necessity of an earlier replacement or even in the damage of numerous electric and mechanical units applied in an agricultural machine. Every waste battery is a threat to the natural environment and is classified as a hazardous waste. The study is devoted to the selection and hierarchization of the criteria for the decision process taking place in the case of an agricultural machine battery purchase.
Key words*: battery, decision process, AHP method*

SELEKCJA I HIERARCHIZACJA KRYTERIÓW PROCESU DECYZYJNEGO WYBORU AKUMULATORA DO SILNIKOWYCH MASZYN ROLNICZYCH Z WYKORZYSTANIEM METODY AHP

Streszczenie

Akumulatory kwasowo-ołowiowe występują we wszystkich silnikowych maszynach rolniczych. Pomimo wielu wad (w szczególności związanych z aspektami ochrony środowiska) posiadają jedną podstawową zaletę, tj. niski koszt zakupu. Czas prawidłowej eksploatacji akumulatorów jest coraz krótszy, zdarza się konieczność ich wymiany już po 2-3 latach. Prawidłowa eksploatacja akumulatora zależy przede wszystkim od właściwie dobranych podzespołów instalacji elektrycznej maszyny rolniczej. Proces decyzyjny związany z zakupem właściwego akumulatora należy do jednego z trudniejszych i odpowiedzialnych w procesie utrzymania maszyn rolniczych. Niewłaściwie dobrany akumulator może powodować nie tylko konieczność jego wcześniejszej wymiany, ale również uszkodzenie awaryjne wielu podzespołów elektrycznych i mechanicznych maszyny rolniczej. Pamiętać należy, że każdy zużyty akumulator stanowi zagrożenie dla środowiska, należy on bowiem do odpadów niebezpiecznych. W pracy przeprowadzono selekcję i hierarchizację kryteriów uwzględnianych w procesie decyzyjnym zakupu akumulatora do maszyny rolniczej.
Słowa kluczowe*: akumulator, proces decyzyjny, metoda AHP*

1. Introduction

The battery is the source of electrical energy produced as a result of direct conversion of chemical energy, being the direct power source for machines [10-12, 17]. Batteries that are worn out or flat may be the reason for the starter motor voltage drop and for the problems with proper volume of engine start revs. The purchase of a new battery is always connected with hard decisions. The battery for an agricultural machine should match its engine capacity as well as power of starter motor, alternator and other units. A mismatched battery is likely to cause premature wear as a result of long-lasting insufficient charge or overcharge.

The majority of the developed and applied methods of selection and hierarchization of decision processes are based on multicriterial nature of this choice. They include a number of methods such as, among others, Analytic Hierarchy Process (abbr. AHP) [22, 23], *Ratio Estimation in Magnitudes or deciBells to Rate Alternatives which are Non-DominaTed* (abbr. REMBRANDT) [13], *Simple Additive Weighting Method* (abbr. SAW) [4], *Fuzzy Simple Additive Weighing Method* (abbr. F-SAW) [26], *Simple Multi-Attribute Ranking Technique* (abbr. SMART) [6], *Simple Multi-Attribute Ranking Technique Exploiting Ranks* (abbr. SMARTER) [7], *Fuzzy Analytic Hierarchy Process* (abbr. F-AHP) [14], *Analytic Network Process* (abbr. ANP) [24], *Fuzzy Analytic Network Process* (abbr. F-ANP) [26], *Measuring Attractiveness by a Categorical Based Evaluation TecHnique* (abbr. MACBETH) [2], the French method *ELimination Et Choix Traduisant la REalia* (abbr. ELECTRE) [15, 18, 28], *Preference Ranking Organisation METHod for Enrichment Evaluations* (abbr. PROMETHEE) [3], *Technique for Order Preference by Similarity to Ideal Solution* (abbr. TOPSIS) [9] and many others. The first stage in these methods includes the selection of the decisive characteristics (parameters) that after the classification in the following stage become decisive criteria. Experts are in charge of the selection of these characteristics. The decisive criteria may be classified in terms of their measurability (measurable and non-measurable characteristics), the extent of their complexity (simple and aggregate), and moreover there can be distinguished also acute and blurred characteristics. The study employs the AHP methodology to select and hierarchize the criteria for decision process concerning the choice of a lead-acid battery applied in agricultural equipment.

2. Materials and methods

The goal of the study is to identify the set of detailed and key criteria for the decision process concerning the purchase of the battery to power-driven agricultural machines, as well as their pairwise comparison and classification by descending impact on the decision making.

The importance of the particular key criteria (that consist of the detailed criteria significance values) was evaluated by means of the pairwise comparison method, so called Analytic Hierarchy Process. The AHP method is a heuristic approach developed by an American researcher T. L. Saaty [20] and combines the elements of mathematics and psychology [1, 5, 27]. It facilitates optimal choices to be made by experts from a particular industry who face multicriterial decision making problems.

To achieve the goal of the study the involved group of 100 farmers who had to make decisions about the purchase of a starting battery. They determined the detailed criteria considered by them, based on their knowledge and experience, to have essential impact on the purchase decision. Afterwards the detailed criteria were grouped into the key ones whose number should, as the adopted methodology assumes, oscillate between 5 and 9. The limitation of the number of criteria is the result of psychological experiments which prove that a single criterion cannot be compared to more than 7±2 other criteria, since it disenables their differentiation [20, 21]. In the next stage, again based on their knowledge and experience, the study participants assigned each criterion of a determined number of points out of a 100-point scale

The provided evaluations constitute a comparison matrix K_{nn}, of $n \cdot n$ dimension, where *n* stands for the number of all the compared criteria. They are arranged consecutively in the headlines of the matrix rows and columns. Its elements are evaluations a_{ij}, put at the intersection point of *i*-this row and *j*-this column, the equation 1:

$$\begin{array}{c|c} & \begin{array}{cccccc} K1 & K2 & \dots & Kj & \dots & Kn \end{array} \\ \begin{array}{c} K1 \\ K2 \\ \vdots \\ Ki \\ \vdots \\ K_n \end{array} & \begin{bmatrix} a_{11}=1 & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\ a_{21} & a_{22}=1 & \dots & a_{2j} & \dots & a_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ a_{i1} & a_{i2} & \dots & a_{ij}=1 & \dots & a_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nj} & \dots & a_{nn}=1 \end{bmatrix} \end{array} = K_{nn}, \tag{1}$$

where: *i, j = 1, 2, ..., n.*

Every pairwise comparison matrix should meet the condition 2:

$$a_{ij} = \frac{1}{a_{ji}}, \tag{2}$$

where: *i, j = 1, 2, ..., n.*

The procedure of the key criteria ranking definition lies in the column-based standardization of the matrix $K_{nn} = [a_{ij}]$ and the matrix $\overline{K}_{nn} = [\overline{a}_{ij}]$, as presented in the equation 3:

$$\begin{array}{c|c} & \begin{array}{cccccc} K1 & K2 & \dots & Kj & \dots & Kn \end{array} \\ \begin{array}{c} K1 \\ K2 \\ \vdots \\ Ki \\ \vdots \\ K_n \end{array} & \begin{bmatrix} \overline{a}_{11}=1 & \overline{a}_{12} & \dots & \overline{a}_{1j} & \dots & \overline{a}_{1n} \\ \overline{a}_{21} & \overline{a}_{22}=1 & \dots & \overline{a}_{2j} & \dots & \overline{a}_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ \overline{a}_{i1} & \overline{a}_{i2} & \dots & \overline{a}_{ij}=1 & \dots & \overline{a}_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ \overline{a}_{n1} & \overline{a}_{n2} & \dots & \overline{a}_{nj} & \dots & \overline{a}_{nn}=1 \end{bmatrix} \end{array} = \overline{K}_{nn}, \tag{3}$$

where: $$\overline{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, \tag{4}$$

The next step is to determine the average significance value of the criteria $\overline{w}_{K,ij}$ in every row of the standardized matrix $\overline{K}_{nn}$, as presented in the equation 5.

$$\overline{w}_{Kij} = \frac{\sum_{i=1}^{n} \overline{a}_{ij}}{n}, \tag{5}$$

where: *i, j = 1, 2, ..., n.*

As a result every above-mentioned criterion obtained as many different significance values $\overline{w}_{Kij}$ as many farmers took part in the study. This in turn requires the definition of the global value $w_{K,i}$ for the criterion K_i, as presented in the equation 6:

$$w_{Ki} = \frac{\sum_{j=1}^{n} \overline{w}_{Kij}}{n}, \tag{6}$$

where: $w_{K,i}$ - a global significance of *i*-this criterion,

$\overline{w}_{Kij}$ – partial value of *i*-this key criterion assigned by a *j*-this study participant,

n – the number of the study participants.

3. Results and discussion

The conducted studies provided the set of hierarchized key criteria for the decision process concerning the choice of a starting battery (Table 1). They include both material and non-material aspects of decision process, which are directly or indirectly related to it. The order of the key criteria listed in the chart below and their symbols are random.

Table 1. The key criteria of the decision process concerning the choice of a starting battery

Tab. 1. Kryteria główne procesu decyzyjnego wyboru akumulatora rozruchowego

Criterion symbol *Ki*	Criterion name
K1	battery price
K2	battery size
K3	battery capacity (ah)
K4	battery start current (A)
K5	vehicle producer’s recommendation
K6	battery brand
K7	voltage (V) and pole placement
K8	service or seller’s recommendation

Source: own work / Źródło: opracowanie własne

The Table 2 presents the evaluation scoring of the hierarchized key criteria for 5 randomly selected respondents. Based on their knowledge and experience, every farmer assigned each criterion a determined number of points out of a 100-point scale. The value "0" was assigned to the key criteria that were, in their opinion, inessential for the battery selection process, whereas "100" was intended for the choices made based on only one key criterion [16].

The individual evaluation scoring of the key criteria submitted by every farmer allows their hierarchization (Table 3).

Table 2. Evaluation scoring of the key criteria significance
Tab. 2. Punktowa ocena ważności kryteriów głównych

No.	Key criteria evaluation scoring							
	K1	*K2*	*K3*	*K4*	*K5*	*K6*	*K7*	*K8*
R1	30	15	10	10	5	5	20	5
R2	30	25	10	0	15	0	15	5
R3	0	0	0	0	0	0	100	0
R4	20	20	20	5	5	5	20	5
R5	15	0	20	15	15	0	25	10

Source: own work / Źródło: opracowanie własne

Table 3. The hierarchization of the key criteria
Tab. 3. Hierarchizacja kryteriów głównych

No.	Key criteria hierarchy
R1	*K1 >> K7 >> K2 >> K3 = K4 >> K5 = K6 = K8*
R2	*K1 >> K2 >> K5 = K7 >> K3 >> K8 >> K4 = K6*
R3	*K7 >> K1 = K2 = K3 = K4 = K5 = K6 = K8*
R4	*K1 = K2 = K3 = K7 >> K4 = K5 = K6 = K8*
R5	*K7 >> K3 >> K1 = K4 = K5 >> K8 >> K2 = K6*

Source: own work / Źródło: opracowanie własne

The sign "=" stands for an equal score in the hierarchy of the analyzed key criteria, in turn the sign ">>" describes different scores they obtained. For the farmer *R1* the most valuable criterion is K1, followed by K7, then by equally evaluated K3 and K4, and finally there are K5, K6, K8 assessed as the least important.

The comparisons made based on the hierarchized system of the adopted key criteria, partially presented in the chart 3, allowed to create the pairwise comparison matrix. The applied evaluation system is presented in the Table 4.

Table 4. The adopted scoring system for the pairwise comparison process
Tab. 4. Przyjęta skala ocen procesu porównywania parami

Score range	Evaluation
0-20	1
21-40	3
41-60	5
61-80	7
81-100	9

Source: own work / Źródło: opracowanie własne

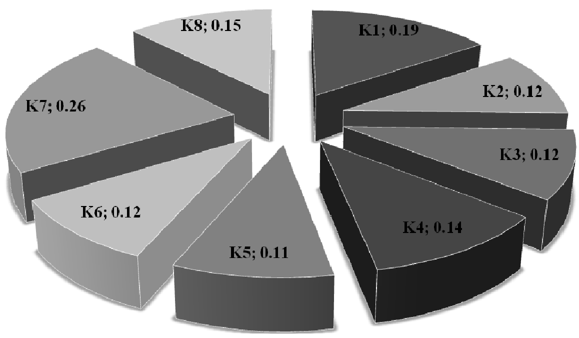
The partial values of the hierarchized key criteria significance (for 5 in 100 study respondents) are presented in the Table 5. The number of significance values of each criterion corresponds to the number of the study respondents. For the user identified as *R1* the most important is the criterion *K1* (significance value of 0.20), i.e. the price of a battery. In turn in the opinion of user *R3* the most important is the criterion *K7*, i.e. voltage and poles placement.

The use of the equation 6 allowed the determination of global values of the key criteria significance for the starting battery purchase decision, and the results are presented in the figure 1. Voltage and poles placement (*K7* is the criteria of the biggest global significance (0.26) which, given the wiring systems construction, does not raise any doubts [8]. The least significance (0.11) is assigned to the criterion *K5*, i.e. vehicle producer's recommendation.

Table 5. The partial values of the key criteria significance
Tab. 5. Wartości wag cząstkowych kryteriów głównych

No.	Key criteria significance partial values							
	K1	*K2*	*K3*	*K4*	*K5*	*K6*	*K7*	*K8*
R1	0.20	0.12	0.12	0.12	0.11	0.11	0.12	0.11
R2	0.18	0.18	0.12	0.09	0.12	0.09	0.12	0.09
R3	0.06	0.06	0.06	0.06	0.06	0.06	0.56	0.06
R4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
R5	0.12	0.11	0.12	0.12	0.12	0.11	0.17	0.12

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 1. The key criteria significance values of the decision process concerning the machinery park modenization
Rys. 1. Wartości wag kryteriów głównych procesu decyzyjnego modernizacji parku maszyn

4. Conclusion

The conducted studies and their analysis show that an important factor affecting the battery purchase decision is its price (significance value of 0.19). This certainly proves low profitability of farms. As Szeląg-Sikora and Wojciech [25] state, the financial aspect plays a key role in farming, and according to Rybacki and others [19] and Osuch and others [16], decisions about technical equipment purchase are predominantly conditioned by price. A very little attention is paid to the battery capacity (0.1) and its start current (0.14), which can cause the change of the battery work in the conditions of insufficient charge or overcharge. A mismatched battery acts to the detriment of a vehicle wiring system and may lead to premature battery wear. As Kamińska and others [10], Kamińska and Skarbek-Żabkin [12] confirm, worn out batteries are hazardous wastes and damage the environment. The selection of a proper lead-acid battery for an agricultural vehicle is the necessity to maintain both high machinery infallibility level and good homestead economic condition, playing also an important role in the environmental protection conditions improvement.

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