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INVESTIGATION OF THE DECISION-MAKING PROCESS OF SELECTION OF SERVICE STATION FOR AGRICULTURAL TRACTORS USING THE AHP METHOD

Summary

The quality of technical services plays a significant role in maintaining agricultural tractors in optimal technical conditions ensuring, in this way, their reliability and durability. Availability of various types of service enterprises creates decision-making problems in selecting optimal ones. The study presents an analysis of the decision-making process of a selection of a service station of agricultural tractors using the method of the analytical hierarchy process (AHP).

BADANIE PROCESU DECYZYJNEGO WYBORU STACJI SERWISOWEJ CIĄGNIKÓW ROLNICZYCH Z WYKORZYSTANIEM METODY AHP

Streszczenie

Jakość serwisu technicznego odgrywa znaczącą rolę w utrzymaniu ciągników rolniczych w optymalnym stanie technicznym, zapewniając tym samym ich dużą niezawodność i trwałość. Funkcjonowanie różnych typów zakładów serwisowych stwarza problemy decyzyjne w wyborze optymalnego. W pracy przedstawiono analizę procesu decyzyjnego wyboru stacji serwisowej ciągników rolniczych z wykorzystaniem metody Analitycznej Hierarchizacji Procesu (AHP).

1. Introduction

In the course of exploitation of agricultural tractors, unavoidable wear of their assemblies and parts as well as of the applied exploitation materials takes place. This is caused by the process of wear which leads to a gradual loss of material and structure deformation of the surface layer as well as changes of dimensions and shape of cooperating parts [4, 5, 6].

This wear can be either normal or accelerated. During the operation of agricultural tractors properly used and serviced, the highest share of wear is due to the friction processes, although they cannot be eliminated altogether, nevertheless knowing their essence and mechanism, it is possible to reduce their intensity effectively. Among the causes of accelerated wear, the following are important: errors in construction or execution technology, improper exploitation conditions, incorrectly executed repairs and improper technical service.

Technical servicing is a necessity frequently requiring exclusion of agricultural tractors from utilisation, sustainment of labour costs and replacement of parts which do not translate into profits coming from the tractor utilisation. In order to fulfil properly their required tasks, systems of technical servicing of agricultural tractors must be continually improved both organisationally as well as with regard to the quality of provided services. Promptness and punctuality as well as the quality of the performed technical service exert a significant influence on the reliability and durability of the agricultural tractors.

Recently, the numbers of service enterprises offering services in the area of technical overhauls of agricultural machines have increased. Apart from the authorised and non-authorised but specialised stations, universal enterprises offering a very wide range of different services have appeared on the market. However, these enterprises are characterised by different quality of the offered assistance not always reflected in the quality of the provided services. Therefore, it was found expedient to investigate farmers' decision-making processes in the course of their selection of the type of the service station for agricultural tractors. The results of these studies will be used by service enterprises to plan directions of their own development.

2. Objective of the study

The brief analysis of the maintenance system specificity of agricultural tractors as well as causes of their natural and accelerated wear clearly indicates a need to make every attempt to ensure high degree of quality of this process as it may exert a significant impact on their durability and reliability.

The decision regarding the choice of a particular service station by a user of an agricultural tractor is made on the basis of different criteria. The aim of this study was to obtain empirical information about these criteria and to arrange them in a sequence in accordance with their importance. The performed investigations were carried out using the AHP method which had been successfully employed for experiments in other sectors of service activities.

3. Material and methods

To realise the objective of the study, a group of users of agricultural tractors who make use of enterprises offering technical services was selected. The following three enterprises were investigated: an authorised service station (Z1), non-authorised but specialised service station (Z2) and a service station offering services for a wide range of different agricultural machines (Z3).

When making decisions about the choice of a particular service station, tractor users who, in the adopted investigation method, were treated as experts take into consideration the following principal criteria: price of the provided service (B1), quality of the provided service (B2), punctuality the provided service (B3) and empathy of the service provider (B4). Each expert allocated a specific number of points (from 0-100) to individual criteria of the concerned service station and, in addition, arranged the adopted principal criteria according to their importance.

The analytic hierarchy process (AHP) method constitutes a heuristic approach developed by an American mathematician T. L. Saaty which combines elements of mathematic and psychology [1, 2, 3, 7]. It facilitates making optimal choices in the case of multicriterial decision problems by their reduction following a series of pairwise comparisons carried out by experts which, in effect, allows numerical measure of the importance of the analysed criteria.

The arguments justifying the choice of the AHP method as a research tool to solve the problem presented in this study were: presentation of the problem in a form of a hierarchical model and possibility of a simultaneous analysis of measurable and non-measurable features.

The problem of the choice of the appropriate service station is presented in Figure 1. The main objective (principal objective) of the performed analyses was the selection of the most optimal solution regarding servicing of agricultural tractors which would take into consideration the adopted criteria.

In accordance with the assumptions of the AHP method, all calculations in this study were performed in three stages:
I. Development of matrices of pairwise comparisons for the three analysed service stations (n=3) separately within the framework of each criterion (matrices $A^{(1)}$, $A^{(2)}$, $A^{(3)}$) and for the criteria alone (matrix $A^{(0)}$). These comparisons lead to the development of four pairwise comparison matrices ($A^{(0)}$, $A^{(1)}$, $A^{(2)}$, $A^{(3)}$). An important complement of the Ist stage is examination of the consistency of experts' assessments.
II. Determination of individual rankings from each of the matrices of the Ist stage.
III. Determination of the multicriterial ranking for the examined service stations.
In the course of pairwise comparisons, a 4-score adjective scale was employed as shown in Table 1.

Table 1. Ranks used during pairwise comparison of objects or criteria (according to Saaty)

Verbal assessment (qualitative)	Numerical assessment (rank)
Equally preferred	1
Equally to slightly	2
Slightly preferred	3
Slightly to strongly	4
Strongly preferred	5
Strongly to very strongly	6
Very strongly preferred	7
Very strongly to exceptionally	8
Exceptionally preferred	9

$A^{(1)}$, $A^{(2)}$ and $A^{(3)}$ matrices are pairwise comparison matrices of all objects consecutively within the framework of each criterion. Matrix $A^{(0)}$ is a pairwise comparison matrix of criteria alone. Each of the pairwise comparison matrices should fulfil the following conditions:

$$a_{ij}^{(k)} = \frac{1}{a_{ji}^{(k)}}, \tag{1}$$

$$a_{ii}^{(k)} = 1, \tag{2}$$

$$a_{ij}^{(k)} = a_{ir}^{(k)} \cdot a_{rj}^{(k)}, \tag{3}$$

where: k=0, 1, 2, 3,

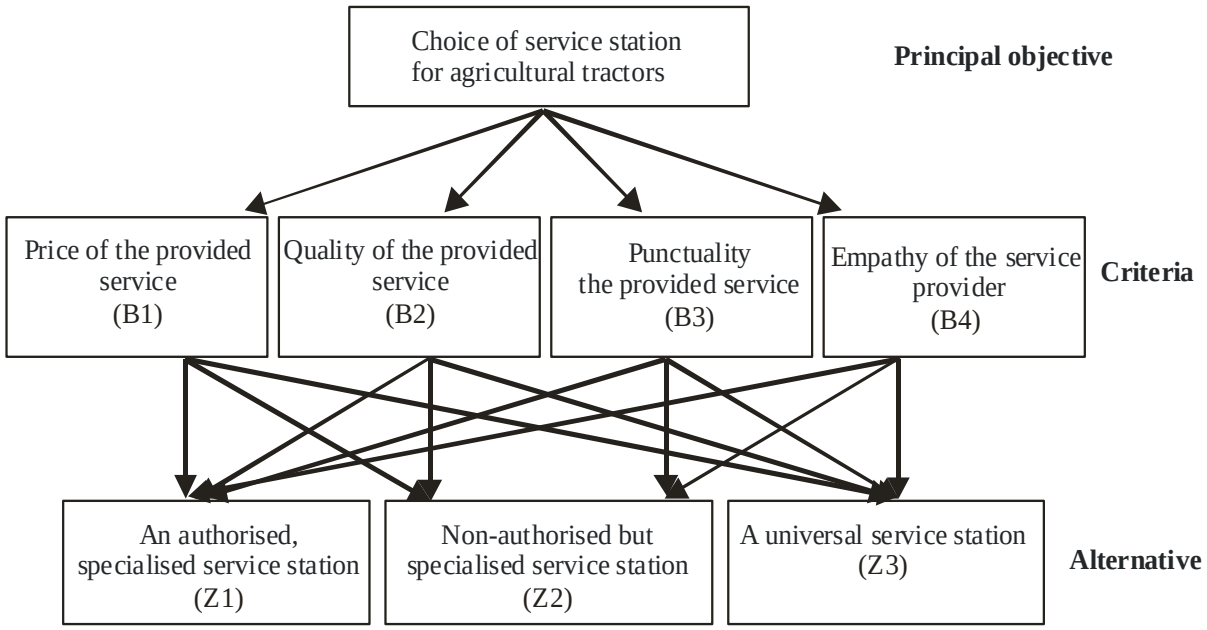

Fig. 1. Hierarchical structure of the choice of service station for agricultural tractors

For each pairwise comparison matrix, the procedure of establishment of individual ranking involves column normalisation of the $A^{(k)} = \left[a_{ij}^{(k)}\right]$ matrix, to the matrix according to the notation $\overline{A}^{(k)} = \left[\overline{a}_{ij}^{(k)}\right]$,

where:

$$\overline{a}_{ij}^{(k)} = \frac{a_{ij}^{(k)}}{\sum_{i=1}^{n} a_{ij}^{(k)}}, \quad (4)$$

Next, the mean $s_i^{(k)}$ value of $\overline{a}_{ij}^{(k)}$ elements is determined in each line of the normalised $\overline{A}^{(k)}$ matrix in accordance with equation 5:

$$s_i^{(k)} = \frac{\sum_{i=1}^{n} \overline{a}_{ij}^{(k)}}{n}, \quad (5)$$

The $s_i^{(k)}$ values are referred to the AHP method as individual preference indices. The column vector $s^{(k)} = \left[s_i^{(k)}\right]$ is the vector of individual ranking. Values of the $s_i^{(k)}$ index indicate the position of the *i* object in the individual ranking within criterion *k* framework, i.e. the higher the value of the $s_i^{(k)}$ index, the higher the position of the *i* object within the framework of a given criterion.

Similarly, for the pairwise comparison of matrices for $A^{(0)}$ criteria alone the value of the $s_i^{(0)}$ index indicates here the position of the criterion *i* in the individual ranking in relation to the remaining criteria, i.e. the higher the value of the $s_i^{(0)}$ index, the more important in the criterion.

The multicriterial ranking in the AHP method is achieved by calculating the multicriterial vector preference indices $P = \left[p_i\right]$. Components of vector *P* are calculated in accordance with equation 6:

$$p_i = \sum_{k=1}^{K} s_k^{(0)} s_i^{(k)}, \quad (6)$$

The value of the multicriterial index of preference indicates the position of a given service station of agricultural tractors in the multicriterial ranking, i.e. the higher the value of the p_i index, the higher the position of the service station (object *i*).

Despite the fact that the pairwise comparison is done by the experts with knowledge in this field, also they can make mistakes in allocating scores. Evaluation of the results reliability is achieved by the calculation of index and coefficient of consistency. In order to eliminate discrepancies, the coefficient of reliability (CR) is calculated according to dependence 7:

$$CR = \frac{CI}{RI} 100\%, \quad (7)$$

where:

RI – random index dependent on the degree of matrix *n*, assuming values according to Table 2;

CI – consistency index, determined from dependence 8:

$$CI = \frac{(\lambda_{\max}^{(k)} - n)}{(n-1)}, \quad (8)$$

where:

$\lambda_{\max}^{(k)}$ - matrix own value;

n- number of considered objects (service stations of agricultural tractors).

Value $\lambda_{\max}^{(k)}$ requires determination of the column vector of partial sums $sw^{(k)} = \left[sw_i^{(k)}\right]$, in accordance with equation 9:

$$sw^{(k)} = A^{(k)} s^{(k)}, \quad (9)$$

after which:

$$\lambda_{\max}^{(k)} = \frac{\sum_{i=1}^{n} \left(\frac{sw_i^{(k)}}{s_i^{(k)}} \right)}{n} \quad (10)$$

4. Results and analysis

Experts (users of agricultural tractors) allocated a specific number of scores to the investigated service stations taking into account the adopted criteria and performed ranking (dividing 100 points) of the adopted principal criteria (Table 3).

Table 2. Saaty`s random indices *RI*

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.54	1.56	1.57	1.58

Table 3. Score assessment of service stations for agricultural tractors

Score for individual criteria (0-100)	Price of technical service	Quality of technical service	Punctuality of technical service	Empathy of service provider
Z1	53	76	66	65
Z2	67	68	73	70
Z3	77	70	58	59
Assessment of weights of adopted criteria (0-100)				
Criterion weight	17	31	29	23

(*source:* own elaboration)

Using points allocated by experts, a numbers of comparisons of alternative service stations of agricultural tractors were made bearing in mind the adopted criteria. For this purpose, the score scale shown in Table 4 was applied.

Tables 5–9 present pairwise comparison matrices, conditions matrices and individual rankings for the adopted criteria.

Table 4. Score scale for the selection of the best service station for agricultural tractors

Difference in score	Assessment
0-5	1
6-10	3
11-15	5
16-20	7
21-25	9

(*source:* own elaboration)

Table 5. Pairwise comparison matrix, normalised matrix and individual ranking for the criterion price of the technical service (B1)

$A^{(1)}$	Pairwise comparison matrix			Conditioned pairwise comparison matrix			∑	Preference index $[s^{(1)}]$
	Z1	Z2	Z3	Z1	Z2	Z3		
Z1	1.00	5.00	9.00	0.76	0.79	0.69	2.24	0.75
Z2	0.20	1.00	3.00	0.15	0.16	0.23	0.54	0.18
Z3	0.11	0.33	1.00	0.08	0.05	0.08	0.21	0.07
∑	1.31	6.33	13.00	1.00	1.00	1.00	3.00	1.00

(*source:* own elaboration)

Table 6. Pairwise comparison matrix, normalised matrix and individual ranking for the criterion quality of the technical service (B2)

$A^{(2)}$	Pairwise comparison matrix			Conditioned pairwise comparison matrix			∑	Preference index $[s^{(2)}]$
	Z1	Z2	Z3	Z1	Z2	Z3		
Z1	1.00	0.33	0.33	0.14	0.15	0.15	0.44	0.15
Z2	3.00	1.00	1.00	0.43	0.43	0.43	1.29	0.43
Z3	3.00	1.00	1.00	0.43	0.43	0.43	1.29	0.43
∑	7.00	2.33	2.33	1.00	1.00	1.00	3.00	1.00

(*source:* own elaboration)

Table 7. Pairwise comparison matrix, normalised matrix and individual ranking for the criterion punctuality of the technical service (B3)

$A^{(3)}$	Pairwise comparison matrix			Conditioned pairwise comparison matrix			∑	Preference index $[s^{(3)}]$
	Z1	Z2	Z3	Z1	Z2	Z3		
Z1	1.00	3.00	0.33	0.23	0.33	0.22	0.78	0.26
Z2	0.33	1.00	0.20	0.08	0.11	0.13	0.32	0.11
Z3	3.00	5.00	1.00	0.69	0.56	0.65	1.90	0.63
∑	4.33	9.00	1.53	1.00	1.00	1.00	3.00	1.00

(*source:* own elaboration)

Table 8. Pairwise comparison matrix, normalised matrix and individual ranking for the criterion empathy of the service provider (B4)

$A^{(4)}$	Pairwise comparison matrix			Conditioned pairwise comparison matrix			∑	Preference index $[s^{(4)}]$
	Z1	Z2	Z3	Z1	Z2	Z3		
Z1	1.00	1.00	0.33	0.20	0.14	0.22	0.56	0.19
Z2	1.00	1.00	0.20	0.20	0.14	0.13	0.47	0.16
Z3	3.00	5.00	1.00	0.60	0.71	0.65	1.96	0.65
∑	5.00	7.00	1.53	1.00	1.00	1.00	3.00	1.00

(*source:* own elaboration)

Table 9. Pairwise comparison matrix, normalised matrix and individual ranking for the considered criteria

$A^{(0)}$	Pairwise comparison matrix					Conditioned pairwise comparison matrix				∑		Preference index $[s^{(0)}]$
	B1	B2	B3	B4		B1	B2	B3	B4			
B1	1.00	5.00	5.00	3.00		0.58	0.50	0.50	0.64	2.22		0.56
B2	0.20	1.00	1.00	0.33		0.12	0.10	0.10	0.07	0.39		0.10
B3	0.20	1.00	1.00	0.33		0.12	0.10	0.10	0.07	0.39		0.10
B4	0.33	3.00	3.00	1.00		0.19	0.30	0.30	0.21	1.00		0.25
∑	1.73	10.00	10.00	4.66		1.00	1.00	1.00	1.00	4.00		1.00

(*source:* own elaboration)

Table 10 presents the final ranking of the assumed criteria taken into account in the course of the decision-making process of selection of a service station for agricultural tractors.

Table 10. Multicriterial ranking in the decision-making process of the choice of the service station for agricultural tractors

Criterion / Index of preferences for examined criteria	B1	B2	B3	B4	=	Multicriterial ranking $[p_i]$	
$s^{(1)}$	0.75	0.15	0.26	0.19		0,51	Z1
$s^{(2)}$	0.18	0.43	0.11	0.16		0,19	Z2
$s^{(3)}$	0.07	0.43	0.63	0.65		0,31	Z2
$s^{(0)}$	0.56	0.10	0.10	0.25			

(*source:* own elaboration)

The best choice from the point of view of the adopted criteria is the authorised service station for agricultural tractors because the maximum value of the measure in the multicriterial ranking equals 0.51.

Table 11 presents values of the consistency ratio (CR) which, according to Saaty, should not exceed 0.1. Higher values indicate inconsistency in the comparison of pairwise alternatives.

Table 11. Values of the consistency ratio CR (n=3, RI=0.52; n=4, RI=0.89)

Criterion/ matrix / Ratio	$A^{(1)}$	$A^{(2)}$	$A^{(3)}$	$A^{(4)}$	$A^{(0)}$
$\lambda_{max}^{(k)}$	3.02	3.00	3.04	3.03	4.04
CI	0.01	0.00	0.02	0.02	0.01
CR	0.02	0.00	0.04	0.03	0.01

(*source:* own elaboration)

The consistency ratio for all matrices of pairwise comparison did not exceed the 0.1 threshold and, therefore, the performed comparison of criteria can be considered as consistent.

5. Conclusions

The performed investigations and analyses led to the formulation of the following conclusions:

1. The AHP method employed in the study allowed precise based on a numerical quality index, hierarchisation of parameters affecting the choice of the service station for agricultural tractors.
2. It is evident from the performed analysis that such criteria as: quality and punctuality of offered tractor technical services are the most important for customers when taking decisions about the selection of a service station. These criteria should be taken into account first, when considering expansion or development of technical services.

6. Literature

[1] Ayag Z.: A hybrid approach to machine-tool selection through AHP and simulation. International Journal of Production Research, 2007, Vol. 45, nr 9, s. 2029-2050.

[2] Doloi H.: Application of AHP in improving construction productivity from a management perspective. Construction Management and Economics, 2008, Vol. 26, s. 839–852.

[3] Durczak K., Rybacki P. Hierarchizacja kryteriów oceny jakości usług serwisowych maszyn rolniczych - opinia konsumenta. Technika Rolnicza Ogrodnicza Leśna, 2011, nr 1, s. 22-24. ISSN 1732-1719.

[4] Rzeźnik C.: Podstawy obsługi technicznej maszyn rolniczych. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, 2002. ISBN 83-7160-265-0.

[5] Tomczyk W.: Obsługi techniczne w procesie odnowy i utrzymania maszyn i urządzeń rolniczych. Inżynieria Rolnicza, 2009, nr 6(115), s. 301-307.

[6] Tomczyk W.: Obsługi techniczne maszyn i urządzeń rolniczych w praktyce. Inżynieria Rolnicza, 2009, nr 6(115), s. 295-300.

[7] Wijnmalen D. J. D., Wedley W. C.: Non-discriminating Criteria in the AHP: Removal and Rank Reversal. Journal of Multi-Criteria Decision Analysis, 2009, Vol. 15, s. 143-149.