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Hierarchy of influence of modern technical solutions used in agricultural tractors on the effectiveness of their work

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Summary. An analysis of the impact of technological and organizational factors on the efficiency of agricultural tractors was made. Importance of modern technical solutions of assemblies used in agricultural tractors was assessed. The study showed that the values of technical and exploitation parameters of the tractor and its availability are more important than the modernity of technical solutions.

Key words: tractor, efficiency, modernity.

INTRODUCTION

Productivity and operation costs of machine units depend on many factors [14,12,13,15,1]. One of them is the modernity of solutions used in agricultural tractors.

The concept of modernity is widely used in agricultural technology, the more that the offer of innovative solutions is a priority for manufacturers of tractors and machinery. Studies made by Francik (2002) show that farmers require to evaluate agricultural equipment in terms of modernity. In the literature the works of [2,3,4] can be found, which demonstrate how to evaluate modernity of technical - construction solution of different models of tractors using neural networks. However, in the available literature no reports were found on how modern technologies in tractors are important and what impact they have on the efficiency of tractors. Thus, the aim of the study was to prioritize the significance of modern solutions in agricultural tractors with regard to other factors affecting the economic efficiency of their work. Moreover, the assessment was made which will identify the specific technical solutions for which the modernity has the greatest impact on the economic efficiency of the tractor.

RESEARCH METHODS

The set research target was accomplished on the basis of expert knowledge using expert and mathematical method called the Delphi method or a method of Delphi [5].

The Delphi method was developed in the 50s in the U.S. center of strategic studies, the RAND Corporation. Since then, the method has been used repeatedly for such needs as health, defense, business, education, information technology and transport. It also found a permanent place in the foresight programs, among others in Japan, South Korea, Germany, France, Great Britain, Hungary and the Czech Republic [6]. The application of the Delphi method in agriculture is presented in the work of [7,8,9,5].

The course of research procedure according to Delphi method is shown in Figure 1.

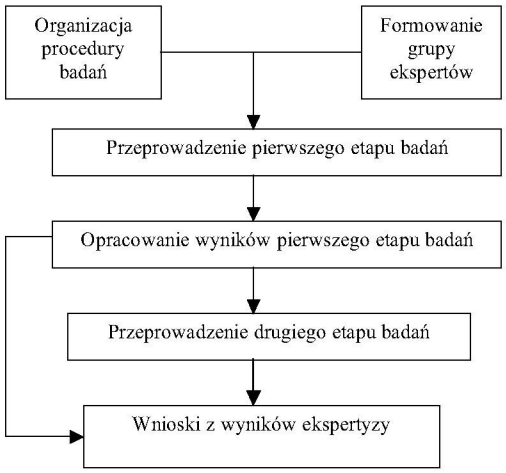
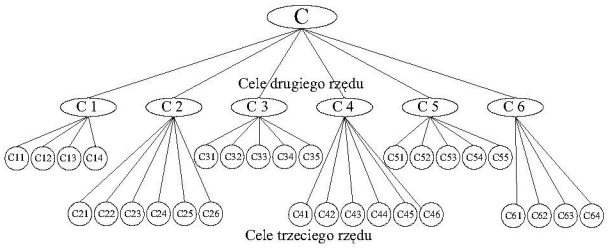


Fig. 1. A diagram of the research using expert and mathematical methods

The basic action in this test procedure was the development of special research questionnaires through which the experts gave their opinions on the issues analyzed.

The study questionnaire included two tables in which the experts noted in the numerical values reflecting their assessment. In order to facilitate the evaluation procedure idea of the event tree was used, also called the Isikawa tree [5]. In it the factors that the experts had assessed were put in groups of factors. In this way the Isikawa tree was created by placing group factors as targets of the second order (Table 1), and factors in each group (objectives III order) at a lower level.

Under the principle of Isikawa tree [5] it was assumed that the impact of all groups of factors is 100 percent. Similar to the impact of each factor included in the group. This principle was in force for experts who have expressed their assessment by breaking 100 percent down into individual factors, thus demonstrating their relevance. In this way, the examiner evaluated separately the significance (importance) of group of factors and individually the factors' significance in a group. Ratings assigned by experts in accordance with the principle of the Isikawa tree are called local priorities [5]



Legend: Cele drugiego rzędu: 2nd order targets; Cele trzeciego rzędu: 3rd order targets

Fig. 2. Event tree diagram (Isikawa diagram)

Information received from the experts in the research questionnaires were entered into the calculation algorithm prepared in Microsoft Excel where the statistical processing according to the principles presented in the literature followed [11,10]. In the first place compliance in assessments given by the experts was analyzed. For this purpose, the concordance coefficient was applied, which in the absence of equal ranks was determined by the formula [11,10].

$$\Theta = \frac{12S}{N_E^2 \cdot (b^3 - b)}$$

In the case of the existence of similar ranks the coefficient of concordance was determined by the formula [11,10].

$$\Theta = \frac{S}{\frac{1}{12} N_E^2 \cdot (b^3 - b) - N_E \sum_{i=1}^{N_E} \cdot T_i}$$

where: S-sum of squared deviations of actual values of ranks, Ne-number of experts, b - number of factors evaluated, T i - index of similar ranks

The sum of squared deviations of actual values of ranks calculated by the formula:

$$S = \sum_{j=1}^{b} (\overline{r_j} - \overline{r})^2$$

where: rj - the sum of ranks given by the experts, to the j-th factor, r - the arithmetic mean of sum of ranks

$$\overline{r} = \frac{\sum_{j=1}^{b} \overline{r_j}}{b}, \quad (18) \quad \overline{r_j} = \sum_{i=1}^{N\acute{Y}} r_{ij}$$

where: rij-rank given by the i-th expert to j-th factor.

Index of similar ranks was calculated by the formula [11,10]:

$$T_i = \frac{1}{12} \sum_{i=1}^{p} (t_i^3 - t_i)$$

where: p - number of groups of equal series in serialization of j-th expert, ti - number of repetitions of equal series in p-th group.

Concordance coefficient is equal to 1 if all of the ranks given by the experts are the same, and 0 there are no equal ranks.

In order to realize that experts' compliance is not accidental χ-square test was used [10,11].

$$\chi^2 = \frac{S}{\frac{1}{12} N_E \cdot b \cdot (b+1) - \frac{1}{b-1} \sum_{i=1}^{N\acute{Y}} T_i}$$

If the calculated value of χ^2 is greater than the tabular χ^2_{tab} and concordance coefficient was significantly different from zero, it was concluded that the compliance of the experts' evaluation is not random [10,11]. Moreover, compliance of judgments of experts was assessed using the coefficient of variation calculated by the formula [10,11]:

$$Vj = \frac{g_j}{\overline{m}} \cdot 100 \quad [\%]$$

where: gj - standard deviation, mj - arithmetic mean of evaluations given by the experts

$$\overline{m_j} = \left(\sum_{i=1}^{Ne} m_{ij} \right) / N_e$$

where: Mij-standadized rate of stature j-th agent designated by the i-th expert

The standard deviation was calculated by the formula:

$$g_j = \sqrt{\frac{\sum_{i=1}^{Ne} \left(m_j - m_{ij} \right)^2}{Ne}} \quad \text{for } N_e > 30$$

According to the literature [10,11] compliance of individual assessments set by the experts was considered sufficient if Vj ≤ 0.25. However, Vj values > 0.3 were considered as insufficient compliance.

In case of discrepancies in the assessments of experts the second phase of the study provided for in the Delphic method was carried out. Group of experts was chosen, whose assessment differed significantly from the average grade in the first stage. Then, questionnaires were sent to them, which show the average evaluations of all experts. These experts were to comment on the mean ratings and express their acceptance or rejection. If successful, the assessment given by the expert were replaced by average rating bringing in this way the expert to the mean.

The test procedure take into account the situation in which the examiner would not agree with the ratings presented. In this case, the method assumed an additional interview with an expert in order to obtain explanations and justifications for given ratings. In accordance with the principles of the Delphic method that obtains satisfactory reasons for evaluations discrepancies from the expert provide valuable information that there are experts, for whom the importance of the factors is different than for others.

In this study, experts who missed the evaluation of factor after consulting and obtaining the opinion of the experts agreed with the opinions of other experts.

RESEARCH RESULTS

As a result of research we have obtained assessments of the factors given by 74 experts representing holdings of between 11 to 1,000 acres located in different Polish regions. Farms represented by experts pursued different lines of production: only crop production, only livestock production and the. A vast group was represented by farms with only crop production and multidirectional production.

Table 1. The hierarchy of importance of factors in terms of impact on the efficiency of agricultural tractors

	Target name	Sum of weights	Mean	Coef. Of variance
C 1	Modernity of solutions applied in a tractor	207	15,0	0,24
C 2	The size of the technical-operating parameters of the tractor (engine power, traction, etc.)	95	21,8	0,21
C 3	Readiness to operate (reliability, effectiveness of the service, supply of spare parts, etc)	132	21,1	0,21
C 4	Tractor operating conditions (the surface field, terrain, etc.)	281	14,6	0,26
C 5	Skills and experience of the operator	241	15,1	0,22
C 6	The organization of works on the farm	340	12,5	0,23
Concordance coefficient			0,305	
χ-square criterion			137,25	

Source: own study

According to experts, the efficiency of agricultural tractors was affected by such factors as : the size of the technical - operating parameters of the tractor (which can include such engine power, the power of WOM and external hydraulics), and readiness of the tractor to work (the level of which depends on parameters such as: reliability, effectiveness of the service, supply of spare parts, etc.). The influence of such factors as the modern technologies used in tractors, in the opinion of experts is lower than the above factors and also is a factor as important as a factor: the skills and experience of the operator. So one can believe that an important activity in order to increase the efficiency of the tractor is to improve the skills of operators.

Table 2. The hierarchy of the impact on the efficiency of agricultural tractors of modernity of individual technical solutions used

	Target name	Sum of weights	Mean	Coef. Of variance
C 21	Modern technical solutions used in the engine	138	20,11	0,22
C 22	Modern technical solutions used in the drive train (clutch, gearbox, axles)	99	19,92	0,22
C 23	Modern technical solutions used in the PTO system	330	12,67	0,25
C 24	Modern technical solutions used in the hydraulic lift system and external hydraulics.	234	16,12	0,20
C 25	Modern technical solutions used in tractor steering , associated with its operation and control	283	14,67	0,24
C 26	The solutions used in cab associated with the work comfort, control of its operation and work of co-operating machinery, obtaining information on the course of work (performance, time, etc.)	201	16,51	0,25
Concordance coefficient			0,449	
χ-square criterion			170,52	

Source: own study

Analysis aimed to demonstrate which modern solutions in tractor components reflect the influence of modern technologies used in agricultural tractors on the effectiveness of their work has shown that the efficiency of agricultural tractor in the greatest extent depends on the modernity of the solutions used in the engine and drivetrain (clutch, gearbox, axles). Subsequently, the solutions used in cab comfort associated with the work, control the work of co-operation of the tractor and the tractor machinery, obtaining information on the course of work (performance, time, etc.) and modern technologies used in the hydraulic lift system and SCV are significant.

CONCLUSIONS

The studies show that a modern technical solutions is not the main factor affecting the efficiency of the tractor. A more important factor is the size of the technical and operating parameters and the operational readiness of the tractor. In the opinion of experts the operator's skill is an equally important factor as compared to modernity, implying that training of operators should be an effective way to increase the efficiency of the tractor.

According to experts, modern technology should be introduced to the engine and drivetrain.

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REFERENCES

1. **Banasiak J., 2008:** Wydajnościowa analiza w procesach eksploatacji maszyn rolniczych. Inżynieria Rolnicza 4 (102): 63-68.
2. **Francik S., 2009:** Metoda oceny nowoczesności techniczno-konstrukcyjnej ciągników rolniczych wykorzystująca sztuczne sieci neuronowe cz. I Założenia metody. Inżynieria Rolnicza 9 (118): 41-47.
3. **Francik S., 2010a:** Metoda oceny nowoczesności techniczno-konstrukcyjnej ciągników rolniczych wykorzystująca sztuczne sieci neuronowe cz. II Modele neuronowe do oceny nowoczesności ciągników rolniczych. Inżynieria Rolnicza 3 (121): 29-36.
4. **Francik S., 2010b:** Metoda oceny nowoczesności techniczno-konstrukcyjnej ciągników rolniczych wykorzystująca sztuczne sieci neuronowe cz. III. Przykłady zastosowania metody. Inżynieria Rolnicza 3 (121): 37-44.
5. **Izdebski W., 2003:** Strategie wyposażenia gospodarstw rolnych w kombajny zbożowe. Wydawnictwo SGGW, Warszawa.
6. **Kowalewska A., Głuszyński J., 2009:** Zastosowanie metody Delphi w Narodowym Programie Foresight Polska 2020 Warszawa publikacja dostępna na stronie: http://www.nauka.gov.pl/fileadmin/user_upload/Nauka/Polityka_naukowa_panstwa/Prognozy_rozwoju/20100104_Zastosowanie_Delphi_w_NPF.pdf (stan z 08.02.2012).
7. **Masiuk A., 1998:** Wpływ profilaktyki eksploatacyjnej na efektywność produkcji mleka. Fundacja Rozwój SGGW, Warszawa.
8. **Skudlarski J., 2002:** Wpływ parametrów techniczno - eksploatacyjnych na efektywność pracy ciągników rolniczych. Rozprawa doktorska. Wydział Inżynierii Produkcji SGGW, Warszawa.
9. **Zając S., 2010:** Ekonomiczno-organizacyjne skutki awarii ciągników rolniczych. Rozprawa doktorska. Wydział Nauk Ekonomicznych SGGW, Warszawa.
10. **Tinjakova V.I., 2006:** Matematicheskije metody ekspertnoj informacji. Voronezskij Gosudarstvennyj Universitet, Voronez.
11. **Trajniov V.A., Trajniov O.V., 2003:** Parametricheskije modeli v ekspertnyh metodah ocenki pri priniati reshenij. Izdatelstvo Prometej, Moskva.
12. **Yakovenko A., Doroshenko L., Plizga K., 2004:** Optimizacja rezimov raboty mashinno traktornyh agregatov. MOTROL Motoryzacja i Energetyka Rolnictwa 6: 317-323.
13. **Yakovenko A., Pietrov L., Sosnowski S., 2005:** The possibilittes of Caterpillar tractor towards energy-sowing. TEKA Komisji Motoryzacji i Energetyki Rolnictwa 5: 240-247.
14. **Zaharchuk V., Plizga K., 2004:** Matematicheskaja modiel dla issledovanija vlijanija rozlichnyh faktorov na ekonomicheskije i ekologicheskije pokazatieli kolesnogo traktora. MOTROL Motoryzacja i Energetyka Rolnictwa 6: 282-286.
15. **Żebrowski Z., 2005:** Modelling and simulation tests of switching on front drive axle at farm tractor. TEKA Komisji Motoryzacji i Energetyki Rolnictwa 5: 254-261.

HIERARCHIA WPŁYWU NOWOCZESNYCH ROZWIĄZAŃ TECHNICZNYCH STOSOWANYCH W CIĄGNIKACH ROLNICZYCH NA SKUTECZNOŚĆ ICH PRACY

Streszczenie. Analizowano wpływ czynników technologicznych i organizacyjnych na efektywność ciągników rolniczych. Znaczenie nowoczesnych rozwiązań technicznych podzespołów stosowanych w ciągnikach rolniczych było oceniane. Badania wykazały, że wartości technicznych i eksploatacyjnych parametrów ciągnika i ich dostępność jest ważniejsza od nowoczesności rozwiązań technicznych.

Słowa kluczowe: ciągnik, wydajność, nowoczesność.