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Analysis of the significance of technological and organizational factors affecting the efficiency of agricultural tractors operation

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Summary. This paper presents a hierarchy of technological and organizational factors affecting the efficiency of agricultural tractors operation. Analysis of the impact of individual components of the tractor on the effectiveness of the tractor's work has shown that the engine has the greatest impact, after that the transmission, lift and external hydraulics follow. The system priorities of the 3rd order objectives showed that the following factors are the most significant for the efficiency of agricultural tractor: the use of electronic fuel delivery control systems and electronic control the operation of the engine auxiliary assemblies, the use of systems for controlling engine operation through on-board computer including the operating parameters of the other components as well as the use of devices that enable a temporary increase in engine power.

Key words: tractor, efficiency, engine, components, efficiency.

INTRODUCTION

Performance of numerous agricultural practices requires the use of machines and tractors, which must fulfill the specified requirements. Compliance with selected expectations is assessed on the basis of the characteristics of quality and is sometimes referred to as efficiency [3]. According to Manteuffel [7], the efficiency is the ratio of any effect (benefit) to expenditure incurred on acquiring it.

To achieve high efficiency of the use of agricultural tractors on the farm, and thus lower production costs, is the primary objective of the farm managers (owners) or people managing the work of these machines [10]. The optimal farm equipment in farm tractors is extremely important [18]. Effectiveness of agricultural tractors depends on their technical level as well as the experience of the operator and the natural and productive conditions of farms [11].

Manufacturers of tractors offer more new models of tractors equipped with a number of additional technical equipment and electronics. These devices are improving the efficiency of agricultural tractor but also increase the price of the tractor, which is why it is important to study factors that influence the effectiveness of their work and determine which ones are the most important.

From a review of the literature can be said that many authors were engaged in examination of the efficiency of agricultural tractors, as well as factors that impact on it. [5, 11, 13, 6, 15, 17, 9, 4, 18]. However, there are no studies in which there are attempts to determine their hierarchy. This situation forces the need for research in this area and for utilitarian knowledge useful not only for farmers but also the manufacturer of agricultural tractors.

OBJECTIVE OF THE WORK

The aim of this study was to prioritize the most important technological and organizational factors affecting the efficiency of agricultural tractors. To conduct the study, primary and secondary sources of information were used. Domestic and foreign literature was used as a secondary source of information. In this paper, however, the fundamental importance was attributed to the primary sources of information obtained during field studies conducted using a questionnaire developed among experts, who were the owners of farms who have used tractors.

THE RESEARCH METHODOLOGY

In order to make a hierarchy of importance of technical and organizational factors affecting the efficiency of agricultural tractors the expert-mathematical method was used [1, 16]. Expert and mathematical method is an effective method that allows for the setting of the hierarchy of importance of technical and organizational factors affecting the efficiency of agricultural tractors. The essence of this method is to use the data received as a result of a scientifically reasoned procedures for collecting, structuring and analysis of information from specialists in that field (experts). Expert and mathematical method allows us to analyze and evaluate very diverse factors, and the results obtained with its use are different from the results from other methods by 6-8%. Hence, this method was used for military, economic and scientific purposes [1, 8, 13].

Obtaining reliable results is associated with the conduct of research according to the established procedure in the method, which assumes the following stages:
– organization of the evaluation,
– selection of experts,
– carrying out research,
– processing test results.

Expert selection was based on the criteria discussed in detail in the literature [12, 13]. The expert group consisted of farmers who are competent users of tractors, with expertise and experience related to the use of farm tractors. The basic requirement for the selection of the farmer was work experience of not less than five years and a minimum of secondary education. A group of experts in accordance with the requirements of the method consisted of competent people with knowledge and experience in the field. The basic requirement was the work experience of not less than five years and a minimum of secondary education. The procedure of forming a group of experts assumed selection of individuals, who have achieved good economic results and production on the farm resulting, inter alia, from their knowledge. Other features that were taken into account, less relevant to the knowledge but also significant in the test procedure were kindness and willingness to participate in the survey.

The method of target selection of experts was used. Candidates for the experts were indicated by the experts from the industry of agricultural technology (such as journalists, agricultural magazines specializing in agricultural technology, local dealers for agricultural tractors and machinery, ODR workers). After the initial conversation and positive verification of the suitability of a person's expertise with regard to the aforementioned criteria, that person was included to the list of experts.

The expertise conducted in the expert and mathematical method is based on the evaluation by experts of many factors that determine the problem. It often happens that these factors are so numerous that it is difficult or impossible to compare and evaluate them by an expert. In this situation it is recommended to use the idea of the event tree (Isikawa tree), which is based on a combination of factors in groups and evaluating separate groups of factors and a separate assessment of factors in the group. This solution, used by the author and some researchers in their studies [inner room 2003, Masiuk 1998, Szpilko 1998] greatly facilitated the expert assessment of factors, and processing the information obtained by the authors. Literature studies, as well as personal experience helped to highlight a number of factors affecting the efficiency of agricultural tractors.

Because of their number, making it difficult to directly assess the validity of the idea, the event tree was used (Fig. 1), highlighting the six groups of factors, so-called second level targets (Table 1). In each group, the factors affecting the group were highlighted, and indirectly affecting the main objective, namely the factors determining the efficiency of agricultural tractors. They are the goals of the third level (Table 2). It is assumed that the impact of the six groups of factors (level II targets) on the amount of losses is 100%. It was assumed similarly, that the impact of factors in this group in total is also 100%.

Special interview questionnaire containing the tables, into which the examiner typed the desired information and evaluation, was developed. Putting goals in separate tables by subject allowed an expert to focus at the moment only on the group parameters, which helped him to assess their validity. Parameters shown in the tables were evaluated by an expert on a scale of 0 to 100, in order to distribute a total of 100 points (per cent) to individual parameters. Assessment equal to "0" assigned to the parameter by an expert meant that this parameter was irrelevant for the expert. The number of points greater than zero reflected the relative importance of the other parameters. The analysis of the research concerned the

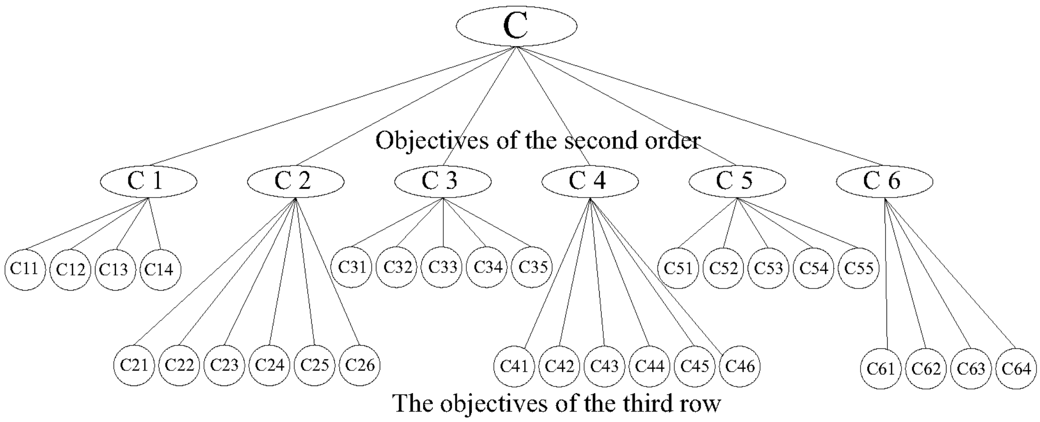

Fig. 1. Event Tree Diagram

importance of the technical solutions used in the different units of tractor in the impact on the efficiency of agricultural tractor. The objectives of the second level of the "Tree of events" highlights the different groups of tractor: engine, transmission, linkage and hydraulics, PTO, cab and steering. At the third level as an objective third row lists the various construction solutions currently used in agricultural tractors. Based on the data obtained from the experts local priorities and systems were calculated and hierarchy of factors made influencing the efficiency of agricultural tractors. Local priorities were evaluated in such a way that the sum of their points in the group was equal to one hundredth. This allowed for the obtainment of numerical values that represent the contribution of individual factors in the structure of the analyzed group.

The questionnaire contained information explaining to the expert how to evaluate the parameters, as well as phone number and email address needed to contact an expert with the author in a situation of having to provide additional guidance and clarification.

THE RESULTS

Based on the survey assessing the validity of 30 factors set out in the form of local priorities by 74 experts was conducted. Age of experts was in the range of 21-56 years, with an average age of 28. The average length of service in the holding of experts was 13 years with the fact that experts regarded the beginning of internship age when they had started independent work on the farm. In many cases, experts began to acquire their experience from the age of 15-16 years.

The experts represented the holdings of between 11 to 1,000 acres located in different Polish regions. Farms represented by experts followed different lines of production: only crop production, only livestock production and the multipurpose production. A vast group was represented by farms with only crop and multipurpose production.

Research analysis pertained to the importance of the technical solutions used in the different units of tractor with regard to impact on the efficiency of agricultural tractor. For this purpose, Isikawa tree was used distinguishing level II targets as individual components of a tractor: engine, transmission, lift and hydraulics, PTO, cab and steering. At the third level as an third level objective the various construction solutions currently used in agricultural tractors were listed. Based on data obtained from the experts local and system priorities were calculated, and hierarchy of factors influencing the efficiency of agricultural tractors was made. Local priorities were evaluated in such a way that the sum of their points in the group was equal to one hundred. This allowed for the obtainment of numerical values that represent the contribution of individual factors in the structure of the analyzed group.

The values of local priorities, which are the average of ratings of individual parameters, coefficients of concordance, rank sum, variance and χ-square test are shown in table 1 and 2. In order to realize that experts' compliance was not accidental χ-square test was used. If the calculated value of χ^2 is greater than the tabular χ^2tab, and the concordance coefficient is significantly different from zero, it can be argued that the compatibility of the experts' ratings is not random [2].

Compliance of expert judgments in local priorities rankings was determined by the coefficient of variance calculated according to the formula [8]. According to the literature it was considered that if $Vj \leq 0.25$, the compliance of individual assessments appointed by experts is sufficient. If Vj 0.3, compliance were considered to be low.

As shown in Table 1 and 2 of the evaluation of experts who were involved in surveying were convergent, which is reflected in the size of the coefficient of concordance (average 0.36), and coefficient of variation in the range of 0,09-0,25. The average value of the χ-square criterion of the tested the third level factors was χ^2obl = 112.92. Array value for the χ-square = 15.10 was χ2tab. One can, therefore, say that in all cases, the following condition is satisfied: χ2obl> χ2tab. The resulting concordance coefficients are significant. This proves that the congruity of expert assessments is not a coincidence either within respondents 'groups' or between them. The determined values of the coefficients of variance also confirmed the compliance of experts' evaluation for both tested levels.

Table 1. Effect of tractor components (targets of the second order) on the economic efficiency of agricultural tractor.

Target label	Target name	Sum of ranks	Average	Variance coef.
C 1	Engine	77	29,7	0,09
C 2	Transmission (gearbox and drive units)	134	25,0	0,16
C 3	Lift and external hydraulics	208	15,2	0,18
C 4	PTO	275	10,7	0,19
C 5	cabin (control – operator's comfort)	281	10,3	0,22
C 6	Steering system	337	9,0	0,25
Concordance coefficient			0,509	
χ-square criterion			188,23	

Sources : own

Analysis of the impact of individual components on the effectiveness of the tractor's work has shown that the engine has the greatest impact, then the transmission, lift and hydraulics follow. Local priorities of design solutions (III level factors) affecting the efficiency of the tractor components are shown in Table 2.

Table 2. The significance of structural solutions to the efficiency of individual systems of tractor

Target label	Target name	Sum of ranks	Average	Variance coef.
Engine				
C 11	The use of mechanical control systems of fuel delivery, and auxiliary subassemblies (eg, turbocharger)	216	22,09	0,22
C 12	The use of electronic control systems fuel delivery and electronic control the operation of the engine auxiliary units (eg, adjusting of cooling fan to the working conditions, turbocharger operation, etc.)	83	28,45	0,12
C 13	The use of devices to allow a temporary increase in engine power	166	24,32	0,18
C 14	The use of systems for controlling engine operation through on-board computer including the operating parameters of other components such as drive system and lift	130	25,14	0,15
Concordance coefficient			0,353	
χ-square criterion			78,47	
Transmission (gearbox and drive units)				
C 21	Alpha The use of mechanical shift and mechanical reverse, front drive and differential lock switch	226	14,64	0,23
C 22	The use of electrohydraulic control and elimination of the need for a master clutch use to change the gears in the transmission, switching on the front drive, differential lock, reverse, etc.	150	21,29	0,17
C 23	The use of systems to maintain a constant speed (tempomat)	311	14,10	0,22
C 24	Using variable gearbox or gear box with a significant number of gears with automatic operation possibility with electro-hydraulic turning on of the reverse, front drive, differential lock (also in auto mode)	86	24,41	0,17
C 25	The use of gear enabling accessing higher transport speeds of the tractor	261	15,51	0,21
C 26	The use of systems for the tractor operation in ride back system (eg TwinTrac)	379	10,04	0,24
Concordance coefficient			0,540	
χ-square criterion			211,54	
Lift and external hydraulics				
C 31	The use of a mechanical system controlling the lift and the external hydraulics	315	12,95	0,25
C 32	The use of electrohydraulic lift and hydraulics control (eg, EHR)	155	22,67	0,19
C 33	Use of systems to enable lift and hydraulics to operate in the automatic mode on the headland, and while working in the field or on the road with the possibility of programming the order of execution steps by these devices and their operating parameters	100	25,24	0,15
C 34	The use in tractor hydraulic system of electronically controlled variable displacement pumps and devices for accessing the various expenses on different outputs of external hydraulics	185	22,88	0,19
C 35	The use of vibration compensation systems for tools mounted on the lift	257	16,26	0,23
Concordance coefficient			0,440	
χ-square criterion			143,30	
WOM				
C 41	The use of mechanical PTO drive switching	255	10,18	0,17
C 42	The use of electrohydraulic PTO drive switch	128	20,60	0,14
C 43	The use of the tractor so called economic speed of PTO	134	19,85	0,21

C 44	The use of automated solutions to switch off the PTO drive at the time of lifting the arm of hydraulic lift and on again on lowering the lift	80	22,52	0,16
C 45	The use of PTO drive circuit switches located on the fender	188	15,63	0,22
C 46	The use of the dependent speed in PTO system equipment	287	11,22	0,24
Concordance coefficient			0,410	
χ-square criterion			137,41	

Target label	Target name	Sum of ranks	Average	Variance coef.
Cabin (control – operator's comfort)				
C 51	Application of systems for parameters monitoring (eg wheel slip, engine load, etc.) and labor productivity of tractor in the form control panel with color display	136	19,1	0,15
C 52	Focusing the control functions in one place such as the armrest with adjustable position and multi-function levers	86	23,1	0,19
C 53	Shock absorbing system of the cab and / or application of the operator seat with automatic shock damping control	197	19,6	0,23
C 54	The use of air conditioning system with automatic temperature control	240	17,3	0,22
C 55	The use of electronic solutions that support the operator in driving such as GPS techniques systems or parallel driving	155	20,9	0,21
Concordance coefficient			0,290	
χ-square criterion			80,45	
Steering system				
C 61	Front axle suspension with the possibility of exclusion	95	25,6	0,19
C 62	Application of solutions to reduce the turning radius of the tractor (eg, turning axles)	162	25,3	0,21
C 63	Application solutions for getting better turning during the field work but with a smaller number of revolutions of the steering wheel	151	24,0	0,18
C 64	Application solutions for moving the tools hanging on the front lift with the tractor wheels turning	119	25,1	0,22
Concordance coefficient			0,130	
χ-square criterion			26,32	

Sources : own

System priorities of III order objectives are shown in Figure 2. As is apparent from the data , three factors C 12, C14 and C 13 stand for more than 23% of the goal accomplishment and eight main factors in the range of II and III for more than 39%. As the analysis shows, in the expert's opinion, three major factors affecting the efficiency of the tractor are: C12 - The use of electronic control systems fuel delivery and electronic control the operation

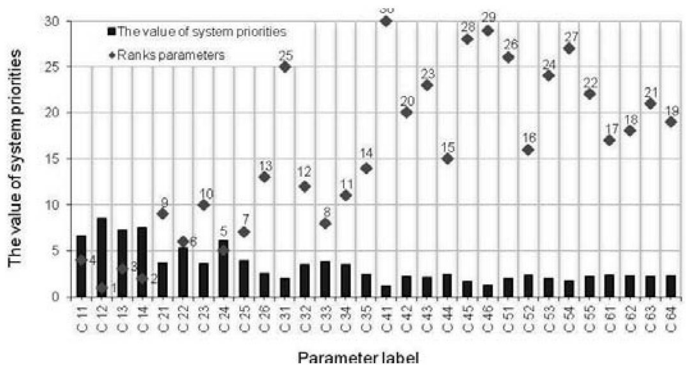

Fig. 2. Ranks and values of the third level system priorities

Source: Own

of the engine auxiliary units, C14 - The use of systems for controlling engine operation through on-board computer including the operating parameters of other components such as drive system and lift, and C13 - The use of devices to allow a temporary increase in engine power.

Subsequently, the priorities of the system were divided into four ranges: high (I), higher than the average (II), medium (III) and lower than the average (IV) by inserting in them the factors whose the priorities of the system are within the ranges of data. Also "the importance of priorities" of range was determined, which means the contribution of group of factors assigned to the range in order to achieve the main goal (Table 3).

CONCLUSIONS

1. Independent expert studies involving 74 experts showed that the three objectives, namely: C12 (The use of electronic control systems fuel delivery and electronic control the operation of the engine auxiliary units (eg, adjusting of cooling fan to the working conditions, turbocharger operation, etc.)), C14 (The use of systems for controlling engine operation through on-board computer including the operating parameters of other components such as drive system and lift), C13 (the use of devices to allow a temporary increase in engine power), for which the system parameters were 8.46, 7.48 ; 7.23, respectively, have the greatest impact on increasing the efficiency of agricultural tractors.
2. Also, the following parameters have a large impact: C11 (the use of mechanical control systems of fuel delivery, and auxiliary subassemblies (e.g. turbocharger)), C24 (using variable gearbox or gear box with a significant number of gears with automatic operation possibility with electro-hydraulic turning on of the reverse, front drive, differential lock (also in auto mode)), C22 (the use of electrohydraulic control and elimination of the need for a master clutch use to change the gears in the transmission, switching on the front drive, differential lock, reverse, etc.) for which the system parameters were 6.57, 6.11, 5.33, respectively.
3. Before the purchase, the prospective tractor buyer should make a detailed analysis of the significance of technical and operating parameters belonging to the first and second system priorities in the range offered on the market of agricultural tractors. Based on this analysis, he should ultimately choose the tractor, whose price and technical performance parameters included in the above-mentioned ranges are the most preferred.

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Table 3. The ranges of system priorities

Range	Range values	Marking of targets included In the range	Range „priority weight" [%]	Average value of system priority In the range [%]
I	6,64-8,46	C 12, C 14, C 13	23,17	7,72
II	4,79-6,63	C 11, C 24, C 22	18,00	6,00
III	2,94-4,78	C 33, C 21, C 23, C 34, C 32	21,83	4,36
IV	1,09-2,93	C 26, C 35, C 44, C 52, C 61, C 62, C 64, C 42, C 43, C 63, C 55, C 53, C 31, C 51, C 54, C 45, C 46, C 41	37,00	2,05

Source: Own

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ANALIZA ZNACZENIA TECHNOLOGICZNYCH I ORGANIZACYJNYCH CZYNNIKÓW WPŁYWAJĄCYCH NA EFEKTYWNOŚĆ PRACY CIĄGNIKÓW ROLNICZYCH

Streszczenie. W pracy przedstawiono hierarchię technologicznych i organizacyjnych czynników wpływających na efektywność pracy ciągników rolniczych. Analiza wpływu poszczególnych elementów ciągnika na skuteczność ciągnika pracy wykazały, że silnik ma największy wpływ, po tym skrzynia biegów oraz pneumatyczna i zewnętrzna hydraulika. System priorytetów celów 3-go rzędu wykazał, że następujące czynniki są najbardziej znaczące dla efektywności ciągnika rolniczego: zastosowanie elektronicznych systemów podawania paliwa sterowania oraz elektroniczna kontrola pracy silnika zespołów pomocniczych, korzystanie z systemów kontroli silnika, praca przez komputer pokładowy, w tym parametrów operacyjnych innych składników, jak również zastosowanie urządzeń, które umożliwiają tymczasowe zwiększenie mocy silnika.

Słowa kluczowe: ciągnik, wydajność, silnik, komponenty, wydajność.