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THE ERGONOMICS AND SAFETY OF FARMING TRACTORS – USERS' OPINION

Summary

In 2017 650 questionnaires were sent online to respondents in the Independent Farmers' Opinion Poll (IFOP) system. The survey provided valuable data for analyses of the safety and ergonomics of tractors used on Polish farms. It showed farmers' subjective preferences with a few parameters determining the overall evaluation of tractors' quality. John Deere tractors were found to be the safest and most ergonomic and they won the first edition of the IFOP project. Users of Case IH and Claas tractors were the most unanimous in their opinions. The respondents found the number of compartments in the driver's cabin to be moderate regardless of the age and make of the tractor.
***Key words**: ergonomics, occupational health and safety, quality, farming tractors, farmers' opinions, IFOP system*

ERGONOMIA I BEZPIECZEŃSTWO CIĄGNIKÓW ROLNICZYCH W OPINII ICH UŻYTKOWNIKÓW

Streszczenie

Na podstawie 650 przesłanych internetowo ankiet, zebranych w systemie NBOR (Niezależne Badanie Opinii Rolników) w roku 2017, uzyskano wartościowe dane do analiz o ergonomii i bezpieczeństwie eksploatacji ciągników będących na wyposażeniu polskich gospodarstw rolnych. Pozwoliły one poznać subiektywne preferencje o kilkunastu parametrach, decydujących o ocenie jakości globalnej ciągników. Stwierdzono np., że najbardziej ergonomiczne i najbezpieczniejsze podczas pracy są ciągniki marki John Deere, zwycięzca I edycji projektu NBOR, najbardziej jednomyślni w swoich ocenach są użytkownicy ciągników rolniczych Case IH oraz Claas, a liczba schowków w kabinie bez względu na wiek ciągnika i markę jest zaledwie umiarkowana.
***Słowa kluczowe**: ergonomia, bhp, jakość, ciągniki rolnicze, opinie rolników, system NBOR*

1. Introduction

According to the physical traits of a product, characterisations of its quality can be classified as: physical, sensory, behavioural, temporal, ergonomic and functional [5]. Apart from utility functions, all products should also be ergonomic and safe to humans, animals, the environment and property. This obvious rule also applies to farming equipment used on each farm, regardless of the specific character of its production.
Farming machinery meets the user's expectations if it meets a set of functional, technological, ergonomic, aesthetic and safety standards. Specific traits grouped in these categories affect the quality of use and operation of machinery and thus, they influence its global quality Q_{MR} [4].

The determinants of product ergonomics and safety are strictly correlated because ergonomic traits affect the safety of using farming machinery. The easiness of operation, quietness in the driver's cabin, good visibility, shape of handles, fastenings, levers, etc. are some determinants of tractor ergonomics. The safety of operation is determined by elements such as lights, anti-slip mats, warning and information pictograms, automatic stability control systems as well as the instruction manual which is legible and easy to understand.

As there are more than one million farms in Poland and they need at least several dozen different types, variants and versions of machinery and appliances to function efficiently [10], farmers face the significant economic problem of wrong purchase decisions.

Operational research is a discipline that deals with the search and development of existing methods aiding the process of making right purchase decisions [6]. For many years the Institute of Biosystems Engineering, Poznań University of Life Sciences, has been successfully conducting this research. One of the latest projects is the IFOP - an Internet platform for collecting farmers' opinions about their machinery and agricultural vehicles.

First, farmers' opinions about tractors were collected. Each farm uses a tractor (there are about 1.4 million farming tractors of more than 50 makes registered in Poland). Like all other vehicles, tractors are periodically replaced with brand-new or second-hand vehicles.

Agriculture is a branch of the economy which chiefly provides food of plant and animal origin. Such high diversity of production forces farmers to operate machines differing in construction and purpose of use. July, August and September are the months when farmers work particularly intensely as it is the time of harvesting and sowing winter crops. Simultaneously, it is the time of higher incidence of accidents, which are chiefly caused by haste, routine, fatigue, carelessness, inadequate organisation of work, disregard of dangers and poor technical condition of machinery [8]. Fortunately, for many years the incidence of farm accidents has been decreasing. Over the last decade it has dropped by nearly 35% [1]. Machines are safer due to the development of economy and technology. The EU directives and national standards require that the machinery available on the market should meet specific standards [2]. Before a machine is offered for sale, it must be marked CE, which indicates that it was individually certified [9, 11].

The 5S good practices of workplace organisation have been extended by a new item. Many companies introduce an additional sixth step, i.e. occupational health and safety. The extended method is referred to as 6S or 5S+1 [7].

Contests and conferences on the subject are very popular. For example, the final of the 15th National Contest 'Safe Farm 2017' took place at the 19th International Agricultural Exhibition Agro Show 2017. Every year the Industrial Institute of Agricultural Engineering in Poznań organises conferences on 'The Safety, Ergonomics and Ecology of Farming Machinery and Tractors'.

2. Aim of study

The aim of the study is to acquire farmers' opinions about the ergonomic characteristics and safety of their tractors from an online questionnaire survey. As farmers have been using tractors for many years, they will be able to indicate the strong and weak points of individual makes and thus facilitate decision-making processes. Manufacturers should receive information which elements of their tractors need major or minor modifications in their construction.

3. Research object and methodology

From March to September 2017 the Internet portal www.nbor.pl provided a rich database based on 650 questionnaires, which showed farmers' opinions about the operation, reliability, ergonomics, safety and attractive design of farming tractors. In total, farmers expressed their opinions about as many as 39 detailed criteria, including 14 criteria related to the subject and aim of this study. The criteria were selected for evaluation by a group of experts who used the brainstorming procedure. The following criteria were evaluated:

- the cabin entrance ES_1
- visibility from the driver's seat (front view, side view) ES_2
- visibility from the driver's seat (rear view) ES_3
- size of the cabin ES_4
- adjustable driver's seat ES_5
- vibration damping ES_6
- noise in the cabin ES_7
- effective ventilation ES_8
- legibility of indicators ES_9
- legibility of the instruction manual ES_{10}
- number of compartments ES_{11}
- external lights ES_{12}
- adjustable steering wheel ES_{13}
- access to control levers ES_{14}.

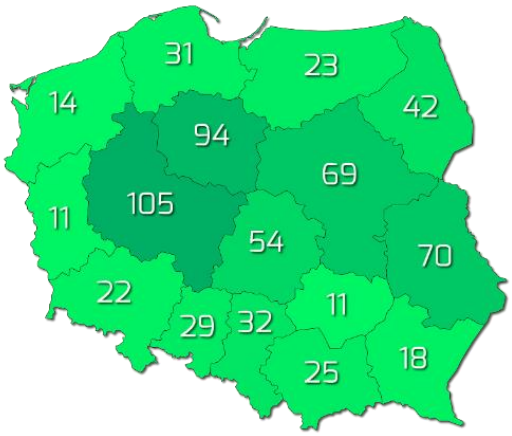
The weights of characteristics were determined at 13% by means of pairwise comparisons (PC), according to the method developed by Thomas L. Saaty. The inconsequent response ratio was as low as 3%, whereas the acceptable limit is 10%. The criteria were evaluated according to a five-point scale, where 1 indicated that a trait was ranked very low, whereas 5 indicated that a trait was ranked very high. There were three intermediate ratings (2 – low, 3 – average, 4 – high).

The data were filtered to eliminate possible errors of the IT system or its user. Specialised software removed duplicates and entries with factual errors from the database. The data were verified qualitatively (data verification and repair) and errors were identified by applying Extract Transform Load (ETL) processes.

First, it was necessary to calculate the arithmetic mean of all ranks referring to individual makes so as to evaluate the ES and the other three characteristics, i.e. F – functionality, R – reliability and A – attractive design. Next, the mean value was multiplied by the weight to calculate the ES index value, which was used in further analyses and quality rankings. The minimum number of 30 questionnaires referring to a particular make was a sine qua non of the ranking to obtain correct and reliable results [3]. Only the mean ES was used for further analyses due to the character of the study.

4. Results

The final results include only 8 out of more than 50 makes of farming tractors registered in Poland, i.e. Case IH, Claas, Deutz-Fahr, John Deere, Massey Ferguson, New Holland, Ursus and Zetor (in alphabetical order). These makes exceeded the minimum of 30 questionnaires (high random sample), whereas there were as many as 29 makes during the first edition of the survey. The most questionnaires came from Greater Poland and Kuyavian-Pomeranian Voivodeships.



Source: the authors' compilation / Źródło: opracowanie własne

Fig. 1. The respondents' activity in individual voivodeships during the first edition of the IFOP (March-July 2017)
Rys. 1. Aktywność oceniających według województw podczas I edycji NBOR (III-VII 2017 r.)

The following numbers of questionnaires referring to individual makes were received and used in the quality ranking:

- John Deere – 92
- Ursus – 83
- New Holland – 81
- Zetor – 80
- Massey Ferguson – 51
- Case IH – 44
- Claas – 38
- Deutz-Fahr – 37.

Measures of dispersion and position of ratings such as their dominant, median, range and mean values were calculated for each make of tractors and for each criterion of their ergonomics and safety (ES). Next, the total mean of all ranks referring to a particular make as well as the ES index, which allows for the weight of this criterion (13%), were calculated. The results are shown in Table 1.

Table 1. The results of measurements and calculations of the tractor ES index in ascending order
Tabela 1. Wyniki pomiaru oraz obliczeń w kolejności rosnącego wskaźnika EB ocenianych ciągników

Make	Parameter	Detailed criteria														Mean ES	ES ratio
		ES_1	ES_2	ES_3	ES_4	ES_5	ES_6	ES_7	ES_8	ES_9	ES_{10}	ES_{11}	ES_{12}	ES_{13}	ES_{14}		
Ursus	dominant	5	5	5	4	3	3	3	3	4	5	3	3	1	3	**3.38**	0.44
	median	4	4	4	4	3	3	2.5	3	4	4	3	3	2	3		
	range	4	3	4	4	4	4	4	4	4	4	4	4	4	4		
	mean	3.86	4.06	3.93	3.70	3.04	2.73	2.52	2.86	3.90	3.92	2.76	3.52	2.35	3.67		
Zetor	dominant	4	5	4	5	5	3	3	3	4	4	3	4	1	4	**3.69**	0.48
	median	4	4	4	4	4	3	3	3	4	4	3	4	3	4		
	range	3	3	3	3	4	4	4	4	4	4	4	4	4	4		
	mean	4.06	4.16	3.92	4.37	3.87	3.34	3.19	3.29	4.06	3.97	3.19	3.82	2.77	3.71		
Massey Ferguson	dominant	5	4	4	5	5	4	4	5	5	4	3	5	5	5	**4.00**	0.52
	median	4	4	4	4	4	4	4	4	5	4	3	4	4	5		
	range	2	2	2	4	4	4	4	4	2	3	4	3	4	3		
	mean	4.35	4.33	4.37	4.06	4.08	3.59	3.73	3.84	4.41	3.90	3.29	4.06	3.71	4.47		
Deutz-Fahr	dominant	4	5	4	5	4	4	4	4	4	4	3	4	4	4	**4.00**	0.52
	median	4	5	4	4	4	4	4	4	4	4	3	4	4	4		
	range	3	2	2	4	2	3	3	4	2	4	4	3	4	3		
	mean	4.19	4.51	4.22	3.84	4.24	3.76	3.95	3.59	4.41	4.00	3.14	4.16	3.73	4.32		
Case IH	dominant	4	4	4	5	4	4	4	4	4	3	2	4	4	5	**4.00**	0.52
	median	4	4	4	4	4	4	4	4	4	4	3	4	4	5		
	range	3	2	2	3	3	3	3	3	2	3	4	2	4	2		
	mean	4.11	4.32	4.27	3.89	4.20	3.82	3.70	3.82	4.41	3.70	2.75	4.20	4.07	4.45		
New Holland	dominant	5	5	5	4	5	4	4	4	5	4	3	4	4	5	**4.08**	0.53
	median	5	4	4	4	4	4	4	4	4	4	3	4	4	4		
	range	3	2	2	3	2	3	4	3	2	4	4	2	3	3		
	mean	4.40	4.37	4.19	4.12	4.15	3.84	3.91	4.14	4.38	4.07	3.15	4.30	4.10	4.28		
Claas	dominant	5	5	5	5	5	5	5	5	5	5	3	5	5	5	**4.23**	0.55
	median	4	5	4.5	5	5	4	4	4	5	4	3.5	5	4	5		
	range	2	3	3	2	3	4	4	3	3	4	4	2	2	2		
	mean	4.32	4.45	4.32	4.55	4.50	4.05	4.08	4.08	4.42	3.95	3.45	4.50	4.39	4.58		
John Deere	dominant	4	5	5	4	5	5	5	5	5	5	4	5	5	5	**4.31**	0.56
	median	4	4	4	4	4	4	5	5	5	4	4	5	4.5	5		
	range	3	4	3	4	4	4	4	3	4	4	4	4	4	4		
	mean	4.30	4.34	4.36	4.08	4.29	4.11	4.40	4.34	4.51	4.18	3.49	4.25	4.32	4.54		

Source: the authors' compilation / Źródło: opracowanie własne

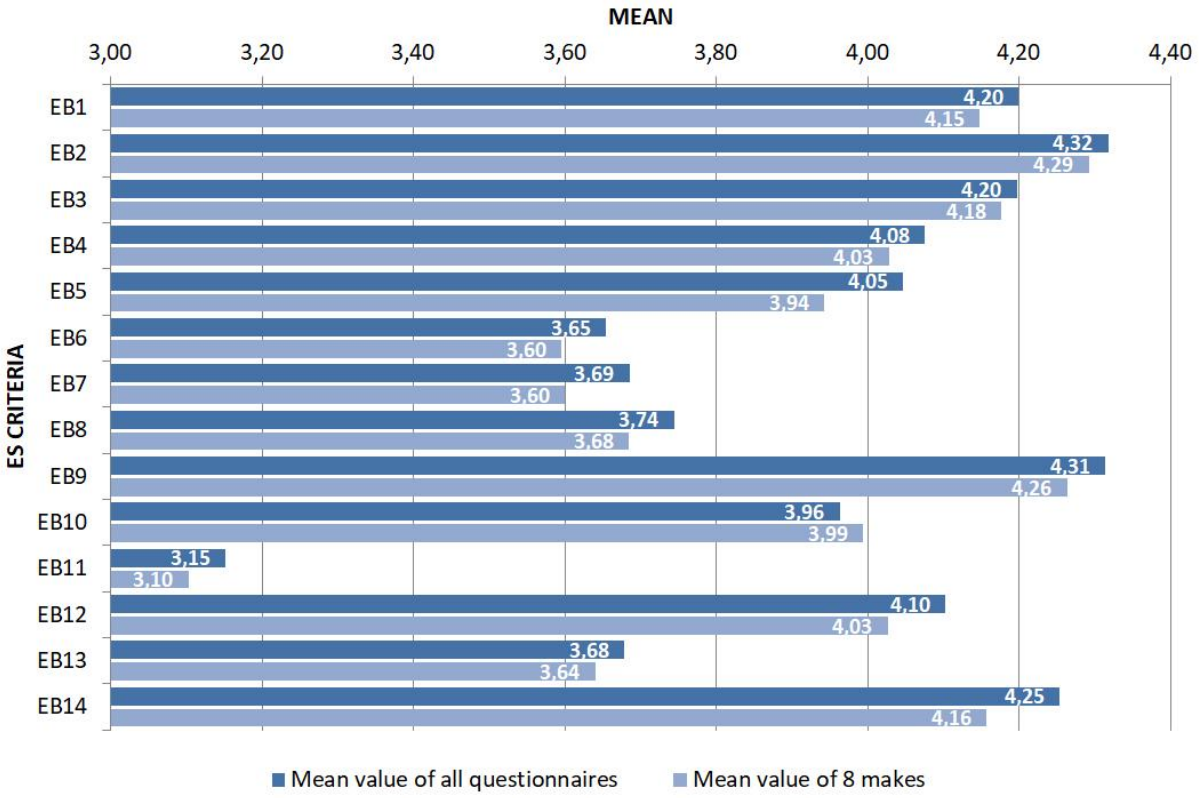
Like in the final ranking of the global quality [3], John Deere tractors also won the ES criterion. The other makes were also ranked high in this criterion. The mean value of all 650 questionnaires rating 14 detailed criteria was 3.90. Only two makes did not exceed this limit.

Next, all the ratings of individual criteria were averaged without division into individual makes. The chart (Fig. 2) shows the values of the ES ratio of all 650 questionnaires and the values which took part in the final ranking.

Among all the available population of 650 tractors, as many as 9 criteria exceeded the limit value of 3.90. The farmers gave the highest rates to visibility from the driver's seat ES_2 and legibility of indicators ES_9. They were the least satisfied with the number of compartments ES_{11} in their tractors.

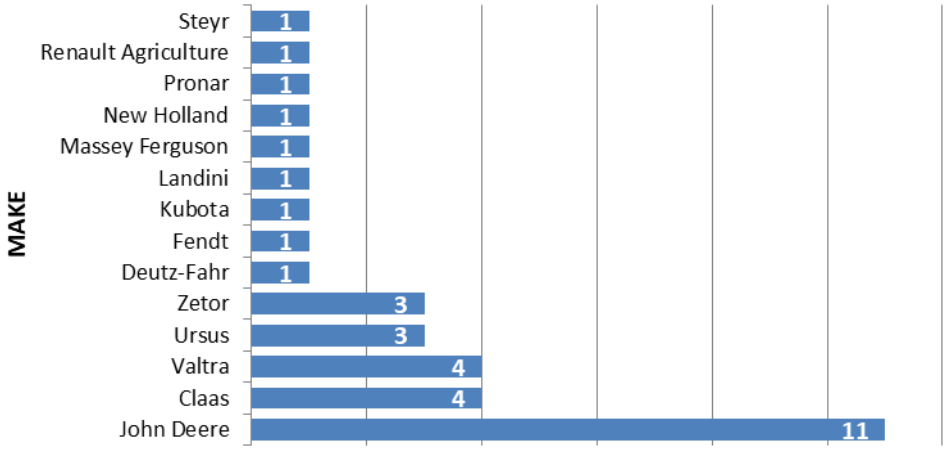
Among the 8 makes of tractors, the mean value of only one criterion – ES_{10}, i.e. legibility of the instruction manual, was rated lower than the global mean (3/99 vs 3.69). This might indicate that 21 classified makes of tractors, which did not exceed the number of 30 questionnaires required by the methodology, were rated high and very high for their ergonomics and safety.

Among all the questionnaires 34 tractors of 7 different makes received the top mean rate in the ES category, i.e. 5.00 (Fig. 3).



Source: the authors' compilation / Źródło: opracowanie własne

Fig. 2. Arithmetic means of 14 detailed criteria in the Ergonomics and Safety category
Rys. 2. Średnie arytmetyczne dla 14 kryteriów szczegółowych grupy Ergonomia i bhp



Source: the authors' compilation / Źródło: opracowanie własne

Fig. 3. The makes of tractors and the number of questionnaires with the maximum value of the ES criterion
Rys. 3. Marki ciągników i liczba ankiet z maksymalną średnią kryterium EB

Table 2. Descriptive interpretations of numerical values of ratings in the five-point scale
Tabela 2. Interpretacje opisowe wartości liczbowych ocen w 5-stopniowej skali punktowej

Point scale	Quality
4.51 - 5.00	excellent
4.01 - 4.50	distinctive
3.51 - 4.00	favourable
3.01 - 3.50	moderate
2.51 - 3.00	intermediate
2.01 - 2.50	unfavourable
1.51 - 2.00	critical
1.00 - 1.50	poor

Source: [3] / Źródło: [3]

According to the assumed linguistic scale (Table 2), these are tractors of excellent quality.

The fitness and efficiency of the human organism is affected by various external factors and safety of the vehicle. It is a natural and obvious fact that these qualities are much lower in old tractors than in new ones. However, there are some exceptions to this rule, because 7 tractors which were older than 20 years were ranked very high by their owners.

5. Summary and conclusions

Although the weight of the Ergonomics and Safety criterion amounted only to 13% of the total number of available percentage points determining the global value of farm-

ing tractors (the weights of the other categories were as follows: Functionality – 42%, Reliability – 18%, Attractive Design – 6%), the manufacturers of tractors need to take this criterion into consideration and develop it in their constructions. It causes higher costs of production, but it indirectly affects the farmer's productivity (the driver is comfortable, not tired, etc.), their health and life as well as the environmental risk. These are intangible, imperceptible and unmeasurable values.

The detailed analysis of the data collected in the first edition of the IFOP project led to the following conclusions:

1. The farmers who took part in the nationwide project evaluating the quality of tractors were satisfied with the ergonomic solutions and safety of their vehicles. High (4) and very high (5) ratings were predominant, so the manufacturers should be satisfied with the farmers' opinions.
2. The values of measures referring to the position and dispersion of random ES variables (means, medians and modes) are very similar. Thus, we can assume that the population curve will be symmetrical and the trait under analysis (evaluation of the ES criteria rated 1-5) will have normal distribution.. This means that there was more or less the same number of ratings which were better or worse than the mean value. This fact is confirmed by the high value of range, i.e. usually 4 or 3. Only the ratings given by 38 owners of Claas tractors and 44 owners of Case IH tractors were very similar.
3. The farming machinery users' eagerness to share their opinions about tractors confirmed the view expressed by the authors of the IFOP system, who found that independent rankings were a valuable source of information not only for clients but also for manufacturers and servicemen. Having considered the remarks made by the respondents in 2017, the researchers began the second edition of the independent farmers' opinion poll about the quality of tractors in Poland. The results will be confronted with the results which are being analysed at the moment.

6. References

[1] Biuro Prewencji i Rehabilitacji KRUS: Wypadki przy pracy choroby zawodowe rolników oraz działania prewencyjne KRUS w 2016 roku. Warszawa 2017.

[2] Borek-Idźkowska I., Adamczyk F.: Ocena bezpieczeństwa użytkowania w kontekście etapów życia maszyny – na przykładzie maszyn do przygotowania pasz. Journal of Research and Applications in Agricultural Engineering, 2011, Vol. 56(2), 21-27.

[3] Durczak K.: Pierwszy polski raport jakości używanych ciągników rolniczych – I edycja projektu NBOR 2017. www.nbor.pl/doc/Raport1_NBOR_2017.pdf.

[4] Durczak K.: System oceny jakości maszyn rolniczych. Rozprawy naukowe 418, Wyd. UP w Poznaniu, 2011, ISNN 1896-1894.

[5] Hamrol A.: Zarządzanie jakością z przykładami. Wydawnictwo Naukowe PWN, Warszawa 2005. ISBN 83-01-14486-6.

[6] Ignasiak E. Praca zbiorowa: Badania operacyjne. Polskie Wydawnictwo Ekonomiczne, Warszawa 2001.

[7] Krawczuk A., Kocira S.: Adaptation of the 6S method in a farm. Journal of Research and Applications in Agricultural Engineering, 2017, Vol. 62(1), 116-121.

[8] Kuta Ł., Cież J.: Ocena poziomu bezpieczeństwa pracy w rodzinnym gospodarstwie rolnym. Journal of Research and Applications in Agricultural Engineering, 2013, Vol. 58(2), 92-97.

[9] Pawłowski T.: Przemysłowy Instytut Maszyn Rolniczych obchodzi swój 70. Jubileusz. Technika Rolnicza Ogrodnicza Leśna, 2016, 2, 2-4.

[10] Rzeźnik C., Durczak K., Rybacki P.: Serwis techniczny maszyn. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, 2015. ISBN 978-83-7160-788-2.

[11] Zbytek Z.: Działalność laboratorium badawczego maszyn rolniczych Przemysłowego Instytutu Maszyn Rolniczych. Technika Rolnicza Ogrodnicza Leśna, 2016, 2, 26-27.