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A NEW VALUATION METHOD FOR TECHNICAL FEASIBILITY OF SERVICING OF AGRICULTURAL MACHINES

Summary

This study presents a new method developed for the valuation of technical feasibility of servicing for agricultural machines based on economic criteria. Moreover, the developed method was verified empirically while analysing selected agricultural tractors. For this reason values of the serviceability index were determined in relation to prices of agricultural tractors. results among the tested tractors the best technical feasibility of servicing was found for Zetor Forterra 105 tractors. The value of serviceability index for this tractor was the lowest (W_{ps}=2.62%).
***Key words**: technical feasibility of servicing, valuation, method, serviceability index*

NOWA METODA WARTOŚCIOWANIA TECHNOLOGICZNOŚCI SERWISOWANIA MASZYN ROLNICZYCH

Streszczenie

W pracy opracowano nową metodę wartościowania technologiczności serwisowania maszyn rolniczych na podstawie kryteriów ekonomicznych. Ponadto dokonano empirycznej weryfikacji opracowanej metody na przykładzie wybranych ciągników rolniczych. W tym celu wyznaczono wartości wskaźnika podatności serwisowej w relacji do ceny ciągników rolniczych. Na podstawie uzyskanych wyników zauważono, że spośród badanych ciągników najlepszą technologicznością serwisowania charakteryzuje się ciągnik Zetor Forrtera 105. Wartość wskaźnika podatności serwisowej dla tego ciągnika była najmniejsza (W_{ps}=2,62%).
***Słowa kluczowe**: technologiczność serwisowania, wartościowanie, metoda, wskaźnik podatności serwisowej*

1. Introduction

Machines during their service life lose their capacity to fulfill their tasks in the function of time. The condition of a machine being unoperational results in its transfer to the technical maintenance subsystem, also called technical service. Technical service is an integral part of the machine operation system [10, 12, 15, 16]. The role of technical service is to maintain the operational condition of machines over an economically reasonable period or a period satisfying the needs of the ma chine's user. It comprises technical inspections, tuning, repairs, overhaul, maintenance and ecological disposal after the machine has been taken out of service.

This operation subsystem has various names, e.g. repairs, overhauls, retrofitting, technical servicing and machine chine maintenance, while at present it is increasingly often referred to as technical service of machines. Such an evolution of the system name is a consequence of technical progress in machine design. In older machines of limited durability and low reliability a dominant role was played by repairs and overhauls. New generation machines of greater durability and reliability make it possible to introduce preventive technical maintenance systems, in which the main role is taken by inspections, tuning and maintenance, thus they are called jointly technical maintenance [2, 4, 9, 11, 13, 14, 17, 18, 19, 20].

Ensuring a high operational standard of modern machines requires a complex system, in which a particularly important role is played by the organisation of a servicing network, availability and identifiability of spare parts, quality and execution time of services, mobility, etc. [1]. Such an understood system is typically referred to as technical service of machines. For this reason this term is commonly used in machine operation practice and it appears increasingly often in scientific publications on the subject. As a result it has become an appropriate, universal and comprehensive term in operation of modern machines [6, 7, 10, 11, 14. 16].

While technical service is provided during machine service life, its course, scope, labour intensity, material consumption, required equipment, etc. are determined already at the stage of machine design and manufacture. It is in these stages of service life of a technical object that serviceability, a crucial operational property of any machine, is determined.

Adaptation of a machine and its assemblies to easy and quick performance of individual technical servicing processes is defined as technical feasibility of servicing. The term of technical feasibility of machine maintenance is also used. Moreover, literature on the subject also uses more specific terms for technical feasibility of servicing, i.e. repair (or overhaul) technical feasibility or repairability [12, 15, 16].

Technical feasibility of servicing is an important utility characteristic of modern machines. Nevertheless, valuation of this property is a difficult and complex task. It is most frequently executed in a descriptive manner by comparing respective characteristics of machines of similar designs and use [12, 16]. Evaluation of technical feasibility of servicing and repairs based on a point score system is more reliable. In the point score evaluation to each characteristic of repair technical feasibility is ascribed a specific number of points and the index of weight of a given characteristic.

Occasionally the point score evaluation system of maintenance technical feasibility is simplified by reducing the number of evaluated characteristics. In such a simplified point score system the evaluation of maintenance technical feasibility is determined by the most essential characteristics, e.g. easy disassembly and assembly, cost and properties of regeneration materials used during repairs, etc. [5, 6, 7, 8, 11, 12].

It is assumed in literature on the subject that assessment based on economic indexes is a more objective method for valuation of technical feasibility of technical maintenance. The index of machine adaptability to technical maintenance is expressed by the ratio of outlays incurred for this maintenance within a specific time period to economic effects obtained from machine use in that period [15, 16]. Repair technical feasibility may also be based on an analysis of technical maintenance costs. When assessing repair technical feasibility we compare costs of repairs (or overhauls) with the utility value of the product. In this way we obtain an index, which is suitable for the assessment of repair technical feasibility for both complete machines and equipment and their assemblies [12].

2. Aim of study

Available literature lacks examples of an objective assessment of adaptation of agricultural machines to efficient performance of technical servicing. For this reason the primary aim of the study was to develop a new, objective numerical valuation of technical feasibility for servicing of agricultural machines. The developed method makes it possible to determine values of the serviceability index based on economic criteria. This index is defined by the relation of values of outlays incurred on technical servicing within a specific period of time in relation to the original value of the used machine.

An additional objective of this study was connected with empirical verification of the developed method based on agricultural machines operated within the strategy of routine technical servicing.

3. Routine technical servicing of machines

The method of execution of technical servicing depends on the adopted strategy of machine operation. In literature on the subject we generally distinguish four basic strategies for the performance of technical service of machines: preventive, focused on reliability, based on technical condition and routine technical servicing [1, 12, 15, 16, 20]. Among them a recommended strategy for machine operation and use is the strategy based on the technical condition. In this strategy operating decisions are made adequately to the temporary, actual technical condition of the machine and forecasted intensity of its changes [20]. However, for technical and economic reasons it is not possible to ensure continuous monitoring of the technical condition for most agricultural machines. For this reason in the operation of agricultural machines the strategy of routine technical servicing required to maintain these machines operational is commonly used. The basic assumptions of this strategy modified by long-term operational experience include cyclicity, hierarchisation and the specified scope of servicing operations. Cyclicity means that servicing operations are performed at a certain constant period of time, expressed in such units as the number of covered kilometers, the number of worked motor hours, years, seasons, etc. As a result of service hierarchisation the higher order technical service, apart from operations characteristic to it, includes also the scope of lower order servicing operations [12, 16].

The assumption that servicing of machines needs to be performed after they have worked for a constant, strictly specified period of time is not completely justified by machine operation practice, since operating conditions, qualifications of machine operators, etc., vary greatly. As a result the intensity of changes in the technical condition for machines of the same type is not uniform and performed servicing operations are not always adapted to their actual technical condition. Occasionally consumables and spare parts are replaced, even though they show no signs of excessive wear. Thus it is assumed that this strategy is connected with high, frequently excessive costs of technical service [1, 16]. Despite these drawbacks the strategy of routine technical servicing of machines facilitates efficient management of machine operation ensuring considerable durability and reliability of machine operation. It is used for various technical objects, including e.g. agricultural machines.

4. Theoretical background for valuation of technical feasibility of servicing for agricultural machines

The primary assumption of the developed valuation method for technical feasibility of agricultural machine servicing implies the analysis of costs of their technical service during the complete servicing cycle. The term servicing cycle refers to the time or amount of performed work between two service operations with the greatest scope or from the beginning of machine service life to the service operation with the greatest scope. In each servicing cycle a specific number of various types of cyclically repeated services is performed in a specific order and specific time periods. Their characteristic feature is the fact that they are performed after the machine has performed a specific number of work units, expressed e.g. in the number of motor hours worked by the tractor. The number of work units, after which a given servicing operation needs to be executed, is called time between overhauls. In most cases machine manufacturers apply the principle that the time between higher order servicing operations is a product of the time between overhauls for lower order service operations. Application of this principle facilitates organisation and management of the servicing process [12].

Each machine has its characteristic set of cyclically repeated services, such as e.g. technical inspections. They create a certain structure, which comprises scopes and repeatability of individual operations and procedures constituting the complete servicing cycle. Each specific structure of the servicing cycle, which should be applied in relation to a given machine, includes all types of servicing activities. The servicing cycle structure has to be determined based on the data provided by the machine manufacturer concerning its servicing system, including information on intervals between overhauls. Determination of the servicing cycle structure for a specific machine makes it possible to assess its total costs of technical service K_{st} in the analysed operation period according to the following equation:

$$K_{st} = \sum_{i=1}^{n} K_i,\ zł, \qquad (1)$$

where:
K_i – cost of performance of servicing of *i*-th type, PLN,
n – number of servicing activities of *i*-th type, performed within a specific machine operation period.

In order to avoid an unstable financial outcome the costs of performance of the technical service processes were compared with the price of the machine. For this service cost index W_{ps} has been introduced based on economic criteria was introduced, which was expressed using the following dependence:

$$W_{ps} = \frac{K_{st}}{C_m} \cdot 100, \%, \qquad (2)$$

where:
K_{st} – costs of technical service incurred within the analysed machine operation period, PLN,
C_m – purchase price of the machine, PLN.

Considering equation (1) the equation for the calculation of values of index W_{ps} for a specific machine takes the following final form:

$$W_{ps} = \frac{\sum_{i=1}^{n} K_i}{C_m} \cdot 100, \%. \qquad (3)$$

According to equation (3), service cost index W_{ps} understood as the ratio of total financial outlays incurred for the performance of cyclically repeated servicing processes within a specific machine operation period to the purchase price of a given machine.

5. Results of empirical verification of the developed method

The developed method was verified empirically based on selected agricultural tractors, which are the basic source of tractive power in Polish agriculture. Analyses were conducted on tractors of similar design and use. As a result tractors selected for this analysis had comparable values of rated power (from 70.5 to 74 kW). The study was conducted in 2011 and covered the following agricultural tractors: Pronar 5135 (70.5 kW), Same Explorer 3 100 (70.5 kW) and Zetor Forterra 105 (74 kW). These tractors were built in 2011 and at the start of the study were new. The length of the servicing cycles of these tractors varied, amounting to 1000, 1200 and 1500 mth, respectively. During the servicing cycle a specific number of technical inspections was performed depending on the tractor make.

During the study information was collected concerning values of components comprising costs of performed servicing operations. They included costs of direct labour and costs of spare parts and consumables, which were used in the performance of technical inspections. Analyses were conducted under comparable workshop conditions for all tractors analysed in this study and it was performed in the "Toral" authorised servicing station in Gostyń (the Wielkopolska province) [3].
Due to the varied duration of the servicing cycle for individual tractors a comparable service life for all tractors, in which a set of necessary information was collected. This period covered the interval from 0 to 1500 mth and it was equal to the longest servicing cycle among selected tractors. Tables 1 to 3 contain results of analyses of technical inspection costs for individual tractors within the assumed machine operation period.

Tab. 1. Costs of performance of technical inspections for Same Explorer 3 100 tractors (C_m = 188190 PLN)
Tab. 1. Koszty realizacji przeglądów technicznych dla ciągników Same Explorer 3 100 (C_m = 188190 PLN)

No.	Frequency of technical inspection (mth)	Costs of parts and consumables (PLN)	Costs of labour (PLN)	Costs of technical inspection K_i (PLN)
1.	50	826	345	1171
2.	300	826	375	1201
3.	600	826	525	1351
4.	900	826	375	1201
5.	1200	2861	570	3431
6.	1500	826	375	1201
Total		6991	2565	9556

Source: the authors' study / Źródło: badania własne

Tab. 2. Costs of performance of technical inspections for Zetor Forterra 105 tractors (C_m = 167390 PLN)
Tab. 2. Koszty realizacji przeglądów technicznych dla ciągników Zetor Forrtera 105 (C_m = 167390 PLN)

No.	Frequency of technical inspection (mth)	Costs of parts and consumables (PLN)	Costs of labour (PLN)	Costs of technical inspection K_i (PLN)
1.	80-100	414	315	729
2.	450-500	435	435	870
3.	950-1000	694	375	1069
4.	1450-1500	1342	375	1717
Total		2885	1500	4385

Source: the authors' study / Źródło: badania własne

Tab. 3. Costs of performance of technical inspections for Pronar 5135 tractors (C_m = 173430 PLN)
Tab. 3. Koszty realizacji przeglądów technicznych dla ciągników Pronar 5135 (C_m = 173430 PLN)

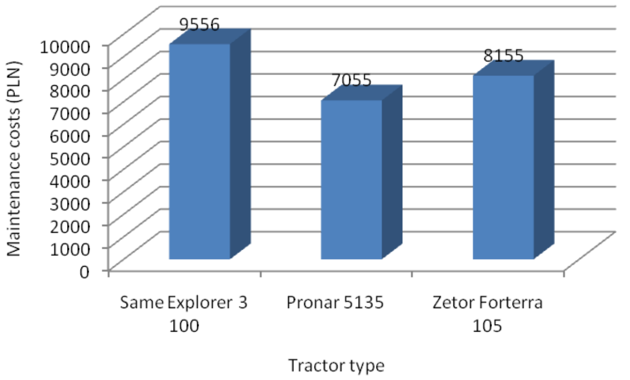
No.	Frequency of technical inspection (mth)	Costs of parts and consumables (PLN)	Costs of labour (PLN)	Costs of technical inspection K_i (PLN)
1.	50	620	315	935
2.	250	990	240	1230
3.	500	1110	330	1440
4.	750	990	240	1230
5.	1000	2840	480	3320
6.	1250	990	240	1230
7.	1500	1110	330	1440
Total		8650	2175	10825

Source: the authors' study / Źródło: badania własne

Based on the results of analyses of costs for individual technical inspections K_i total costs were established for technical service K_{st}, incurred within a comparable period of tractor operation (from 0 to 1500 mth) – equation (2). Fig. 1 presents total costs of technical service K_{st} incurred in the assumed operation time for analysed agricultural tractors.

The value of financial outlays incurred for the performance of technical service of analysed tractors in the period from 0 to 1500 mth ranged from 7055 to 9556 PLN depending on the tractor make. The relatively lowest costs of technical service were recorded for Pronar 5135 (7055 PLN). In turn, for the other tractors these costs were greater and amounted to 8155 PLN (Zetor Forterra 105) and 9556 PLN

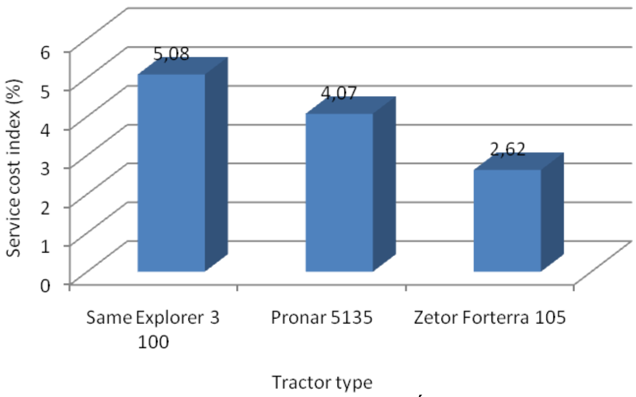
(Same Explorer 3 100). In accordance with the developed method the obtained total costs of technical service were referred to purchase prices C_m of individual tractors (equation 3). The determined value of the service cost index W_{ps} in relation to prices of analysed tractors are presented in Fig. 2.



Source: the authors' study / Źródło: badania własne

Fig. 1. Total costs of technical service for analysed agricultural tractors

Rys. 1. Łączne koszty serwisu technicznego badanych ciągników rolniczych



Source: the authors' study / *Źródło*: badania własne

Fig. 2. Value of service cost index for tested agricultural tractors

Rys. 2. Wartość wskaźnika kosztów serwisu dla badanych ciągników rolniczych

The values of serviceability index W_{ps} in relation to prices of analysed tractors range from 2.62 to 5.08%, depending on the tractor make (Fig. 2). The lowest value of serviceability index was obtained for Zetor Forterra 105 (W_{ps} = 2.62%). In contrast, for the other tractors greater W_{ps} values were recorded, amounting to 4.07% (Pronar 5135) and 5.08% (Same Explorer 3 100). This means that financial outlays for routine technical servicing within the comparable machine operation period in relation to the value of these tractors are greater than in the case of Zetor Forterra 105.

6. Concluding remarks

Development of theoretical foundations for the technical service valuation method and its empirical verification based on selected agricultural tractors make it possible to formulate certain generalisations, which lead to the following conclusions:

On the basis of the values of the W_{ps} service cost values determined in the tests, it can be stated that for different tractors there are different relation of service costs to machine price.

The developed method enables the extension of the data set in the range of economic and operational indicators of agricultural machinery.

The value of service cost index W_{ps} for analysed agricultural tractors ranged from 2.62 to 5.08%. The lowest value of this index was recorded for Zetor Forterra 105 (W_{ps} = 2.62%). This means that the tractor was characterized by the smallest maintenance costs in a comparable service life, relative to the purchase price of that tractor.

Operation with good serviceability provides a potential to reduce costs of technical service, which as a consequence results in a decrease in operation costs of machines and technical equipment used in agricultural production processes.

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