DETERMINING AGRICULTURAL MACHINERY LIFETIME BY USING ECONOMIC INDICATORS

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ABSTRACT
Determining lifetime is a key point in the technical operation of agricultural machinery. A variety of technical and economic indicators may be used about that. The paper offers an approach for determining the lifetime of agricultural machinery on the basis of funds spent for purchasing (capital losses) and financial resources for the maintenance and repair of the equipment.

Key words: agricultural equipment; lifetime

INTRODUCTION
Determining the lifetime of agricultural equipment is a key point in its technical operation and maintenance. Pursuant to the standard (1), developed by the American Society of agricultural engineers, equipment used in production is replaced due to: occasional break-down after which the recovery of operability is unprofitable; productivity of the agricultural machinery does not comply with the requirements of production; obsolete equipment, such being the equipment that is no longer manufactured by industry and spare parts for its repair are missing; reliability of the equipment is very low (unpredictably long outage is observed due to the occasional failures of various components); losses from implementing a planned repair result in an increase in the relative financial losses per unit of performance.

According to the same standard, the term lifetime of agricultural machinery measured in years, is a time interval after which the relative financial losses per unit of performance calculated for the entire lifetime, reach the minimum level and begin to rise. Moreover, the part of the relative financial losses,

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\[ S_i = S_0 \cdot A \cdot B'^i / 100, \]  
where \( S_0 \) is the initial value of the machines; 
\( A, B' \) - coefficients governed by the (3) and having the value shown in table 1.

### Table 1. Values of the coefficients \( A \) and \( B \) for various types of agricultural machinery according to (3).

<table>
<thead>
<tr>
<th>Type of agricultural machinery</th>
<th>( A )</th>
<th>( B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractors</td>
<td>68</td>
<td>0,92</td>
</tr>
<tr>
<td>All kinds of harvesters</td>
<td>64</td>
<td>0,885</td>
</tr>
<tr>
<td>Self-propelled sprayers</td>
<td>56</td>
<td>0,885</td>
</tr>
<tr>
<td>Other field machinery</td>
<td>60</td>
<td>0,885</td>
</tr>
</tbody>
</table>

Taking into account inflation \( \alpha \) [\%], formula (1) shall be the following:

\[ S_i = C_0 \cdot A \cdot B'^i \cdot \left(1 + \frac{\alpha}{100}\right)^i. \]  

Inflation may not be taken into account if it is assumed that \( C_0 \) is the value of similar new agricultural equipment at the time of evaluation of the old available agricultural machinery of the same type.

2. Determine the decrease of value of the agricultural equipment upon revaluation at the end of the \( i^{th} \) year.

\[ D_i = S_{i-1} - S_i \]  

3. Determine the total decrease of the value of agricultural equipment to the end of the \( i^{th} \) year.

\[ D = \sum_{i=1}^{n} D_i, \]  

4. Determine the income from use of the machinery.

At the \( i^{th} \) year of operation of agricultural machinery, the magnitude of income from the use of machinery \( I_i \) is equal to \( b \) simple percentage of the average annual capital (or the average residual value of machinery between two successive revaluations):

\[ I_i = \frac{b}{100} \cdot \frac{S_i + S_{i-1}}{2}, \]  

where \( S_i \) is the residual value of the machinery after revaluation at the end of the \( i^{th} \) year;

5. Determine the total income from the use of machinery to the end of the \( i^{th} \) year.

\[ I = \sum_{i=1}^{n} I_i. \]  

6. Determine capital losses resulting from the operation of agricultural machinery.

Capital losses do not depend on the performance of agricultural machinery and the intensity of its use (4) and in this case they comprise losses in value of machinery in their annual revaluation due to depreciation \( D \) and losses of income with investments \( I \):

\[ C_{K3} = D + I \]  

7. Determine the technical resource of agricultural equipment to the end of operation (measured in amount of cultivated area for a certain number of years)

\[ T_{PKE} = q \cdot i \]  

where \( q \) is the annual volume of production, measured in cultivated area;

\( i \) – the number of the year.

The statistical formula for the technical resource \( T_{PKE} \) to the end of operation of the agricultural machinery (in hours) followed by (4, 5):

\[ T_{PKE} = \int_{0}^{\tau_{a3}} P_{E3}(\Delta t) dt, \ h \]  

where \( P_{E3}(\Delta t) \) is the probability of flawless operation of the relevant agricultural machine.
for specific observed times intervals $\Delta t$ for which statistical information has been collected; 

$T_{OTP_i}$ - the time interval for the $i^{th}$ major and routine repairs of agricultural machinery.

The probability of flawless work $P_{BP}(\Delta t)$ of the relevant agricultural machine is determined by the formula (4, 5):

$$P_{BP}(\Delta t) = \exp\left[-\int_{0}^{T_{OTP_i}} \omega(t)dt\right],$$  

(10)

where $\omega(t)$ is the intensity of the flow of failures of the agricultural equipment measured in fault/h.

8. Determine the losses from routine maintenance and repair.

According to (1), the dependence of accumulated financial losses for technical maintenance and repair $C_{TOP}$ from the time of use of the machinery for the entire technical resource to the end of operation has the form:

$$C_{TOP} = S_0 \cdot l(T_{PKE} / 10^3),$$  

(11)

where $S_0$ is the initial value of machinery; $m, l$ - parameters of the regression equation.

Expression (11) is an estimate and it is obtained as a result of the use of regression analysis in the processing of data about intensity of the flow of faults and the value of their removal for various types of agricultural machinery. Experimental values of the parameters $m$ and $l$ of the regression equation are shown in table 2 (3).

9. Determine the lifetime of agricultural machinery.

$$C = \left(C_{K3} + C_{TOP}\right) / q \cdot i$$  

(12)

Lifetime of the agricultural machinery is the number of years $i$ corresponding to the minimum value of $C$.

The application of the presented approach for determining the lifetime of agricultural machinery may be demonstrated by specific calculation for ploughing. The calculation for determining the lifetime is shown in table 3 for $b = 8\%$ and plough Vogel & Noot MS 950 with an initial value of 13000 € with annual cultivation of 200 hectares per year, i.e. $q = 200$ ha/year.

Table 3 shows that the lifetime of the plough is 10 years, because $i=10$ corresponds to the minimum financial losses made for ploughing 1 hectare of land.

<table>
<thead>
<tr>
<th>Type of agricultural machinery</th>
<th>$m$</th>
<th>$l$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tractors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with two leading wheels</td>
<td>0,007</td>
<td>2,0</td>
</tr>
<tr>
<td>with four leading wheels and chains</td>
<td>0,003</td>
<td>2,0</td>
</tr>
<tr>
<td><strong>Soil-cultivation machines</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ploughs</td>
<td>0,290</td>
<td>1,8</td>
</tr>
<tr>
<td>disc harrow</td>
<td>0,180</td>
<td>1,7</td>
</tr>
<tr>
<td>cultivators</td>
<td>0,270</td>
<td>1,4</td>
</tr>
<tr>
<td><strong>Grain drill</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grain harvesters</td>
<td>0,120</td>
<td>2,3</td>
</tr>
<tr>
<td>beet harvesters</td>
<td>0,590</td>
<td>1,3</td>
</tr>
<tr>
<td><strong>Other machinery</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer spreader</td>
<td>0,630</td>
<td>1,3</td>
</tr>
<tr>
<td>land sprayers</td>
<td>0,410</td>
<td>1,3</td>
</tr>
<tr>
<td>Air-carrier sprayer</td>
<td>0,200</td>
<td>1,6</td>
</tr>
</tbody>
</table>

**Table 2. Values of the parameters $m$ and $l$ for determining the losses from technical maintenance and repair.**
Table 3. Results of sample calculation of the lifetime.

<table>
<thead>
<tr>
<th>i</th>
<th>$S_i$</th>
<th>$D_i$</th>
<th>D</th>
<th>I</th>
<th>$I_{i,q}$</th>
<th>$C_{K3}$</th>
<th>i.q</th>
<th>$C_{TOP}$</th>
<th>$C_{TOP}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6903</td>
<td>6097</td>
<td>6097</td>
<td>796.1</td>
<td>796.1</td>
<td>6893.1</td>
<td>200</td>
<td>208.06</td>
<td>35.5</td>
</tr>
<tr>
<td>2</td>
<td>609.2</td>
<td>793.8</td>
<td>6890.8</td>
<td>520.5</td>
<td>1316.6</td>
<td>8207.4</td>
<td>400</td>
<td>724.52</td>
<td>22.33</td>
</tr>
<tr>
<td>3</td>
<td>5406.6</td>
<td>702.6</td>
<td>7593.4</td>
<td>460.6</td>
<td>1777.2</td>
<td>9370.6</td>
<td>600</td>
<td>1503.19</td>
<td>18.12</td>
</tr>
<tr>
<td>4</td>
<td>4784.8</td>
<td>621.8</td>
<td>8215.2</td>
<td>407.7</td>
<td>2184.9</td>
<td>10400.1</td>
<td>800</td>
<td>2522.92</td>
<td>16.15</td>
</tr>
<tr>
<td>5</td>
<td>4234.6</td>
<td>550.2</td>
<td>8765.4</td>
<td>360.8</td>
<td>2545.7</td>
<td>11311.1</td>
<td>1000</td>
<td>3770</td>
<td>15.08</td>
</tr>
<tr>
<td>6</td>
<td>3747.6</td>
<td>487</td>
<td>9252.4</td>
<td>319.3</td>
<td>2865</td>
<td>12117.4</td>
<td>1200</td>
<td>5234.41</td>
<td>14.46</td>
</tr>
<tr>
<td>7</td>
<td>3316.6</td>
<td>431</td>
<td>9683.4</td>
<td>282.6</td>
<td>3147.6</td>
<td>12831</td>
<td>1400</td>
<td>6908.31</td>
<td>14.1</td>
</tr>
<tr>
<td>8</td>
<td>2935.2</td>
<td>381.4</td>
<td>10064.8</td>
<td>250.1</td>
<td>3397.7</td>
<td>13462.5</td>
<td>1600</td>
<td>8785.31</td>
<td>13.9</td>
</tr>
<tr>
<td>9</td>
<td>2597.7</td>
<td>337.5</td>
<td>10402.3</td>
<td>221.3</td>
<td>3619</td>
<td>14021.3</td>
<td>1800</td>
<td>10860.05</td>
<td>13.823</td>
</tr>
<tr>
<td>10</td>
<td>2298.9</td>
<td>298.8</td>
<td>10701.1</td>
<td>195.9</td>
<td>3814.9</td>
<td>14516</td>
<td>2000</td>
<td>13127.9</td>
<td>13.822</td>
</tr>
<tr>
<td>11</td>
<td>2034.6</td>
<td>264.9</td>
<td>10966</td>
<td>173.3</td>
<td>3988.2</td>
<td>14954.2</td>
<td>2200</td>
<td>15584.83</td>
<td>13.88</td>
</tr>
</tbody>
</table>

CONCLUSIONS
With this work, the authors consider that the described approach for determining the lifetime of machinery by the economic indicators is realizable and applicable to the conditions of the industry "Agriculture" in the country.

REFERENCES
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