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Fixed and variable machine costs taking into account a specific planned residual value

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KTBL planning data have been extended to incorporate the residual value of machinery based on useful life and usage. To calculate the costs of machinery for model farms, it is necessary to include a realistic estimation of the costs of machines that are used beyond the depreciation threshold. At the end of such machines' useful life, they have a residual value that is not negligible. As residual value depends on both the usage and the useful life of a machine, it affects the allocation of machine costs, namely of depreciation and interest costs. The distinction between „below or beyond the depreciation threshold", which was standard in the past, no longer holds. Part of the depreciation and interest costs is assigned to the fixed costs which do not vary with usage, while the other part is assigned to the variable costs which vary depending on usage. This influences the calculation of the minimum use of machinery.

Keywords:
Machine costs, depreciation, interest costs, residual value, minimum use

Machinery represents a significant cost item for agricultural farms. In annual cost accounting, depreciation is used to allocate the acquisition costs of agricultural machinery and equipment used over several years over the respective time period. Depreciation is the difference between the acquisition value and the residual value. In the past, the assumption underlying KTBL planning data was that a machine is used until its depreciation threshold and that it has a residual value of € 0. A closer look at online trading platforms for used machines reveals that the usage of machines varies considerably, decisively affecting the estimated residual value of a machine.

Machine costs are basically composed of depreciation, interest costs, insurance costs, storage, repair and fuel costs (Schroers and Sauer 2011). Depreciation represents the difference between the acquisition value and residual value at the end of a machine's useful life or of the planning period. In operational forecasts, interest costs are derived from the average committed capital. Residual value – that is, the value of a machine at the end of its useful life – increases the average amount of capital committed to machinery. For calculations of planned costs, the acquisition value, planned useful life and planned usage are usually known. However, the achievable residual value is an uncertain variable. Thus, KTBL provides planning data for residual value in order to support the calculation of costs for farm-specific usages.

The residual values of agricultural machinery and equipment have repeatedly been the subject of scientific studies over the past decades. Cross and Perry (1996) examined the topic in detail, focusing on the American agricultural machinery market. They showed that, for the data set under study, the residual value of machinery is determined by the independent variables: age, usage, condition and net farm income (as a proxy for the general situation of the agricultural sector). Wu and Perry (2004) derived a function which can be used to calculate residual values. This function provides an

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estimation of the residual value of a machine depending on its age and usage and on the net farm income (again as a proxy for the general situation of the agricultural sector).

The KTBL working group focusing on „Calculation of machine and facility costs for planning agricultural operations" also investigated this topic. Based on the results of this group of experts, KTBL has offered an online calculation application called MaKost since November 2017. This application can be used to estimate the residual value of machines based on their useful life and usage. In this way, machine costs can be calculated for different useful lives and usages.

Problem and aim

The planned residual value calculated using the KTBL approach is derived from the acquisition value, the relative useful life and the relative usage. Thus, the depreciation and interest costs also depend on the useful life and usage. While simultaneously considering useful life and usage, the approach allocates depreciation and interest costs to both fixed costs (which vary with age, but not with usage) and variable costs (which are usage-based). The aim of this article is to derive and justify this allocation of costs.

Estimation of residual value by KTBL

The above-mentioned KTBL working group developed the following formulae to estimate the residual value of agricultural machinery (Equations 1.1 to 1.3). The relative useful life UL_{rel} equals the useful life UL in relation to potential economic utilisation UL_{pot}. Potential economic utilisation is defined as the period in which a machine becomes technically obsolete; it corresponds to the planning period for replacing a machine, measured in years. The relative usage U_{rel} represents the usage U in relation to potential technical utilisation U_{pot}. Potential technical utilisation is defined as the number of units of use beyond which a machine is worn-out through use, measured in machine-specific units of usage (h, t, ha ...).

$$V_R = V_A - Dep_t - Dep_p \quad \text{(Eq. 1.1)}$$

$$V_R = a \cdot V_A - b \cdot UL_{rel} \cdot V_A - c \cdot U_{rel} \cdot V_A \quad \text{(Eq. 1.2)}$$

$$V_R = V_A \cdot (a - b \cdot UL_{rel} - c \cdot U_{rel}) \quad \text{(Eq. 1.3)}$$

V_R: Residual value
V_A: Acquisition value
Dep_t: Time-based depreciation
Dep_p: performance-based depreciation
a: Factor new price (proportional residual value of the machine at first registration)
b: Factor useful life (weighting factor for performance-based depreciation)
c: Factor usage (weighting factor for time-based depreciation)
UL_{rel}: Relative useful life (useful life in relation to potential economic utilisation)
U_{rel}: Relative usage (usage in relation to potential technical utilisation)

Data sets from the Schwacke List (Eurotax-Schwacke GmbH 2013) and the profi tractor evaluations (profi 2006, profi 2014) were analysed using simple regression analyses to create a functional representation of how the value of tractors and self-propelled vehicles of various manufacturers develop over their service life. This analysis yielded the following findings: It revealed a high loss of value at the beginning of the period of use and an almost linear development of value in the years thereafter. As the scope of the underlying data stock did not allow an in-depth regression analysis with all the necessary tests, a pragmatic approach was adopted. This involved approximating a function that represents the influence of useful life and usage on residual value. The factors for useful life and usage were estimated and tested using data from the Schwacke list. They are therefore not based on comprehensive statistical analyses, but are rather an interpretation of the regression functions. Thus, the experts derived the estimated values for the influencing variables useful life and usage from the analyses. The function currently serves as a working hypothesis which needs to be verified by additional statistical analyses.

The influence of useful life and usage is currently estimated to be equally high across all machine groups on average. Nevertheless, it can be assumed that there are differences between the individual machine groups, with the loss in value of a machine being more strongly influenced by its useful life or by its usage. To compute planned residual values using Equation 1, the KTBL working group calculated the following values for Factors a, b and c as part of an analysis for tractors and self-propelled vehicles:

$a = 0.74$

$b = 0.27$

$c = 0.27$

If usage is at the capacity utilisation threshold (UL_{rel} and $U_{rel} = 1$), the residual value is 20% of the acquisition value. The relative useful life is calculated using Equation 2:

$$UL_{rel} = \text{useful life } UL \,/\, \text{potential economic utilisation } UL_{pot} \qquad \text{(Eq. 2)}$$

The relative usage is calculated using Equation 3:

$$U_{rel} = \text{usage } U \,/\, \text{potential technical utilisation } U_{pot} \qquad \text{(Eq. 3)}$$

The relative useful life and the relative usage reflect the degree to which the machine-specific potential utilisation has been exploited in comparison to the corresponding absolute values (useful life, usage). In addition, the different reference bases for each machine group (different potentials and units) are neutralised so that the above-mentioned factors a, b and c can be applied across all machine groups.

This computation of residual value which simultaneously considers useful life and usage can be represented graphically as a surface in three-dimensional space (Fig. 1).

In the following sample calculations, a machine with an

- acquisition value of € 100,000 is assumed to have
- a potential economic utilisation of 12 years and
- a potential technical utilisation of 10,000 hours.

Figure 1 shows the range of results for different combinations of useful life and usages and the Factors a, b and c, which were estimated by the working group.

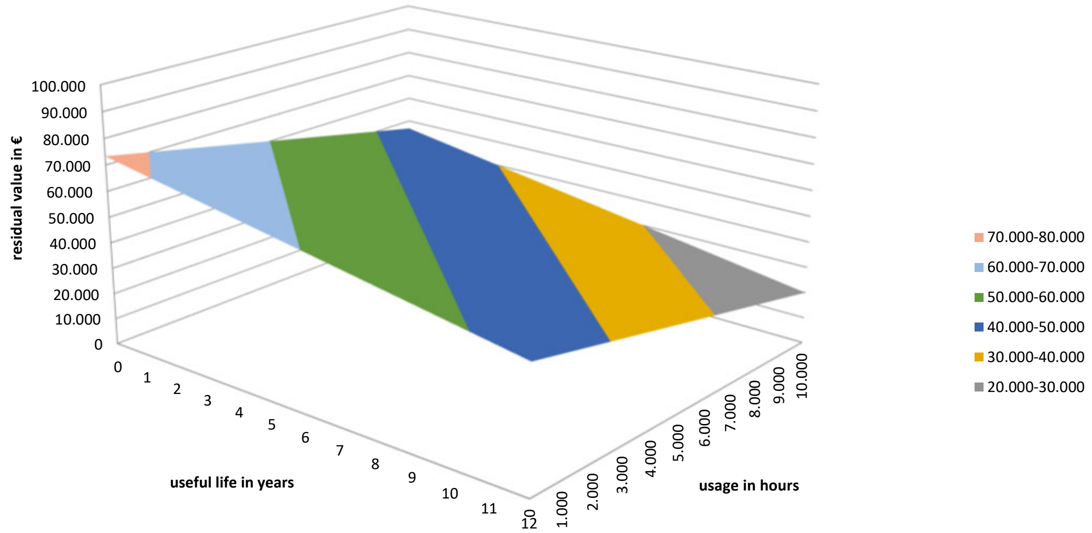

Fig. 1: Residual value of a new machine depending on useful life and usage

This relationship can be depicted two-dimensionally with four sample use scenarios. The following graph shows how the residual values develop over the useful life of 12 years with a usage of 0 h/a, 500 h/a, 833 h/a and 1,200 h/a (Figure 2).

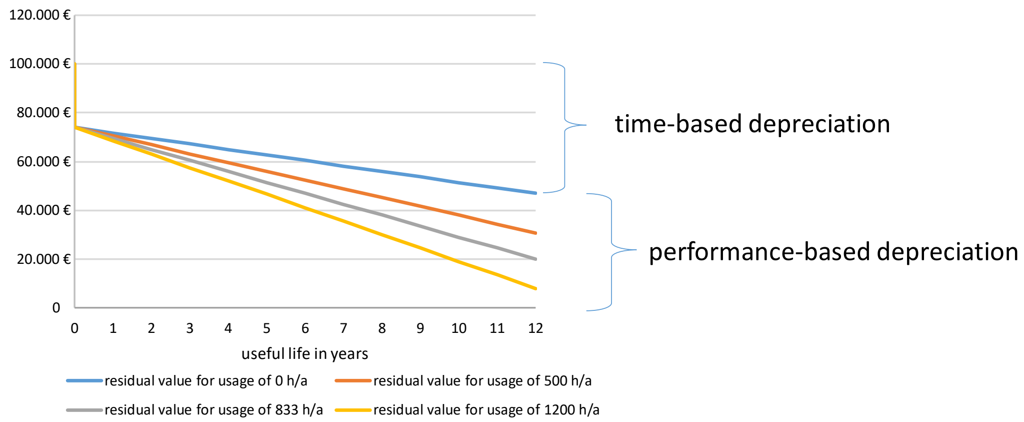

Fig. 2: Development of residual values of a new machine for four different annual usages

Time- and performance-based depreciation – fixed and variable costs

Applications of the concept of depreciation above or below the depreciation threshold have distinguished between two cases to date. Below the depreciation threshold (potential technical utilisation n / potential economic utilisation N), machines are depreciated with a time-based method, since potential economic utilisation limits the useful life of a machine. Total depreciation is considered to be time-based and is therefore assigned to the fixed costs. If annual usage exceeds the depreciation threshold, potential economic utilisation cannot be exploited in years. Usage is thus limited by potential technical utilisation, and the machine is depreciated using an performance-based approach. In this case, total depreciation varies depending on the performance and is therefore assigned to the variable costs.

The KTBL formula for calculating residual value quantifies the loss in value based on both useful life and usage. Thus, the residual value can be calculated for farm-specific useful lives and usage. However, because the formula simultaneously considers useful life and usage, the depreciation costs (= acquisition value - residual value) are partially allocated to the fixed costs and partially to the variable costs.

The loss in value over useful life is accounted for by time-based depreciation and is allocated to the fixed costs. It is calculated as follows (Equation 4):

$$Dep_t = V_A \cdot (1 - a) + V_A \cdot b \cdot UL_{rel} \qquad \text{(Eq. 4)}$$

The loss in value due to usage is accounted for by performance-based depreciation and is therefore considered to be a variable cost. It is calculated as follows (Equation 5):

$$Dep_p = V_A \cdot c \cdot U_{rel} \qquad \text{(Eq. 5)}$$

The formulae can be used to calculate the total amount of time-based (fixed) or performance-based (variable) depreciation over the useful life of a machine. To calculate the relevant amounts of annual depreciation, the overall amount calculated using Equations 4 and 5 is divided by the useful life in years. The same approach is used to calculate the time- and performance-based depreciation per unit of use for a specific group of machines. To calculate total depreciation (Dep_T) , the results from Equations 4 and 5 can be added together, or the formula for calculating depreciation (depreciation = acquisition price - residual value) can be used with the relevant residual value (Equation 1.2).

Time- and performance-based interest costs – fixed and variable costs

The residual value estimated using the method set out above impacts both depreciation and average committed capital and, as a result, the interest costs. In KTBL operational forecasts, the interest costs correspond to the opportunity costs for average committed capital. Total average committed capital is calculated using Equation 6.

$$C_Ø = (V_A \cdot a + V_R) / 2 \qquad \text{(Eq. 6)}$$

$C_Ø$ = average committed capital

Example for 100% utilisation of capacity (= annual utilisation 833 h/year):
$C_Ø$ = (€ 100,000 · 0.74 + € 20,000) / 2 = € 47,000

Because a new machine is assumed to decrease in value by 26% of its acquisition price (Factor a = 0.74), implying a capital commitment period of 0 years, this amount is not included in the calculation of average committed capital. When useful life and usage are simultaneously taken into account, the residual value and, as a result, committed capital are determined by time- and performance-based loss of value. Average fixed committed capital corresponds to the difference between the acquisition price and the residual value resulting solely from ageing of the machine (Equation 7).

$$C_{Øf} = (V_A \cdot a + V_{R0}) / 2 \quad \text{(Eq. 7)}$$

$C_{Øf}$: average fixed committed capital
V_{R0}: Residual value for usage 0 h/year

Example for 100% utilisation of capacity (= annual utilisation 833 h/year):
$C_{Øf}$ = (€ 100,000 · 0.74 + € 47,000)/2 = € 60,500

Average variable committed capital is derived from the additional loss in value through usage. Usage also decreases the residual value and the committed capital. Therefore, the variable interest costs drop with increasing use (Equation 8).

$$C_{Øv} = (Dep_p)/2 \quad \text{(Eq. 8)}$$

$C_{Øv}$: average variable committed capital

Example for 100% utilisation of capacity (= annual utilisation 833 h/year):
$C_{Øv}$ = € 27,000 / 2 = € 13,500

Usage reduces the residual value by the amount of performance-based depreciation. Correspondingly, the amount of average committed capital is reduced by half of the performance-based depreciation. If the usage reaches the depreciation threshold – at the end of usage, relative age and relative usage equal 1 – this corresponds to half of 27% of the acquisition value.

Based on average variable or fixed committed capital calculated in this way, the equations for calculating the related interest costs are derived in the following. In Equation 9, the interest costs are considered as a whole; in Equation 10 the fixed interest costs are considered, and in Equation 11 the variable interest costs are considered. Because usage reduces average committed capital by half of performance-based depreciation, the interest costs are also reduced by the same proportion. This therefore results in negative variable interest costs.

$$C_{int} = C_{int\_f} + C_{int\_v} \quad \text{(Eq. 9.1)}$$
$$C_{int} = (V_A \cdot a + V_R) / 2) \cdot p_c \quad \text{(Eq. 9.1)}$$
$$C_{int} = ((V_A \cdot a + (V_A - Dep_t - Dep_p)) / 2) \cdot p_c \quad \text{(Eq. 9.2)}$$

C_{int}: Interest costs
C_{int_f}: Fixed interest costs
C_{int_v}: Variable interest costs
V_A: Acquisition value
p_c: Interest rate
Dep_t: Time-based depreciation
Dep_p: Performance-based depreciation

Sample calculation of interest costs for 100% utilisation of capacity (= annual utilisation 833 h/year):

€ 1,815 € + (−405 €) = € 1,410

((€ 100,000 · 0.74 + € 20,000) / 2) · 0.03 = € 1,410

((€ 100,000 · 0.74 + (€ 100,000 − € 53,000 − € 27,000)) / 2) · 0.03 = € 1,410

$$C_{int\_f} = ((V_A \cdot a + V_{R0})/2) \cdot p_c \quad \text{(Eq. 10)}$$

V_{R0}: Residual value for usage 0

Sample calculation of fixed interest costs for 100% utilisation of capacity (= annual utilisation 833 h/year):

((€ 100,000 · 0.74 + € 47,000) / 2) · 0.03 = € 1,815

$$C_{int\_v} = ((-Dep_p) / 2) \cdot p_c \quad \text{(Eq. 11)}$$

Sample calculation of variable interest costs for 100% utilisation of capacity (= annual utilisation 833 h/year):

€ −27,000 / 2 · 0.03 = € −405

When the residual value formula is used, the loss in value that occurs with the initial registration of the machine is also taken into account (Factor a = 0.74). This leads to a loss of 26% of the acquisition value of the machine right at the beginning of its use, i.e. immediately after the new machine is purchased. When calculating the interest costs (opportunity costs of capital commitment), this share is not taken into account, because it has a 0-year period of capital commitment (Figure 3).

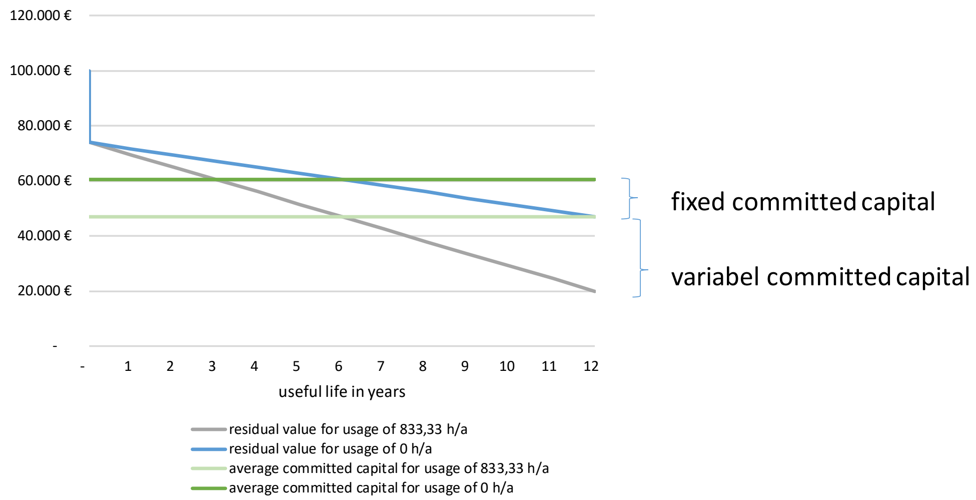

Figure 3: Average committed capital of a new machine depending on age and usage

Calculation of contribution margin and minimum use of machinery

When calculating the minimum use of machinery, the fixed costs of a machine are divided by the contribution margin of the machine per unit of use. The contribution margin equals the monetary performance net of variable costs. The monetary performance of a machine is derived from the price of an equivalent service or rental machine. Based on the KTBL method for estimating residual value, the variable costs equal the sum of variable depreciation, (negative) variable interest costs and the variable operating material and repair costs. Table 1 illustrates the influence of the age- and usage-based calculation of residual value on the minimum use of a machine with an example of a machine rental.

Table 1: Comparison of the calculation using the previous method (without planned residual value) and taking into account a residual value based on useful life and usage (with planned residual value)

Without KTBL planned residual value		With KTBL planned residual value	
Calculation method	**Example**	**Calculation method**	**Example**
$MU = C_{fix} / CM$		$MU = C_{fix} / CM$	
$CM = P - C_v$		$CM = P - C_v$	
$MU = C_{fix} / (P - C_v)$		$MU = C_{fix} / (P - C_v)$	
$C_{fix} = C_{dep} + C_{int} + C_{ins}$	€ 8,333/a + € 1,500/a + € 400/a = € 10,233/a	$C_{fix} = C_{dep\_t} + C_{int\_f} + C_{ins}$	€ 53,000/12 a + € 1,815/a + € 400/a = € 6,631.66/a
$C_v = C_{rep} + C_{fuel}$	€ 7/h + € 12/h = € 19/h	$C_v = C_{rep} + C_{fuel} + C_{dep\_p} + C_{int\_v}$	€ 7/h + € 12/h + € 2.70/h + (€ −0.49/h) = € 21.21/h
P	Rent € 40/h	P	Rent € 40/h
CM	€ 40/h − € 19/h = € 21/h	CM	€ 40/h − € 21.21/h = € 18.79/h
$MU = C_{fix} / CM$	€ 10,233/a /(€ 21/h) = **487 h/a**	$MU = C_{fix} / CM$	€ 6,631.66/a / (€ 18.79/h) = **353 h/a**

MU: Minimum use
CM: Contribution margin
P: Monetary performance
C_{fix}: Fixed costs
C_v: Variable costs
C_{dep}: Depreciation without application of the KTBL planned residual value
C_{dep_t}: Time-based depreciation
C_{dep_p}: Performance-based depreciation
C_{int}: Interest costs without application of the KTBL planned residual value
C_{int_f}: Fixed interest costs
C_{int_v}: Variable interest costs
C_{ins}: Insurance costs
C_{rep}: Repair costs
C_{fuel}: Fuel costs

By factoring in variable depreciation and variable interest costs, the annual fixed costs and the contribution margin are lower, thus decreasing the calculated minimum use. Each operating hour is allocated a certain amount of variable depreciation and negative variable interest costs. Table 1 shows a comparison of a calculation applying the new cost structure with a calculation using the previous cost structure. The example demonstrates that the minimum use is lower when the planned residual value is taken into account. Although a higher proportion of costs is allocated to the variable costs to reduce the contribution margin, this results in a decrease in the fixed costs.

Conclusions

KTBL publishes standard values for acquisition values, economic and technical utilisation potential as well as for repair and operating material costs. Until now, depreciation costs were calculated based on the assumption that machines are used until their depreciation threshold and have a residual value of €0 at the end of the planning period. By supplementing machine-related planning data with residual value based on a machine's specific useful life and usage and the corresponding depreciation and interest costs, realistic estimations of costs for specific usages can be made and used to draw up operational forecasts. Furthermore, it is possible to quantify the decrease in value brought about by usage. This increases the accuracy of forecasting, for example, when calculating the necessary minimum use in the context of investment planning.

The KTBL "Calculation documents" work program is currently running a project that involves collecting data in order to weight time- and performance-based depreciation for additional groups of machines. The working hypothesis is that the significance of the factors for calculating residual value differs depending on the machine groups. For example, some machines that are subject to considerable wear do not lose much value because of their useful life. This is because there is little technical progress. On the other hand, other low-wear machines might no longer be used because a farm's operations have grown and, as a result, they no longer have sufficient power (cultivator) or transport capacity (transport trailer) to meet the farm's requirements. For smaller farmers, however, investing in such discarded machines is a technically viable option, because the machines' usage to date has only minimally affected their residual value. As a rule, however, both a machine's life and its usage lead to a loss in value, so that it is unlikely that either of the two factors equal zero.

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