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Cost of machinery, installations and operational equipment

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1 General Principles

Durable resources include those assets that are available for use in the long-term (> 1 year) by the operation. They include land, land improvements (meliorations), permanent crops, buildings and structures, as well as machinery, implements and operating devices.

1.1 Outline of the costs for permanent resources

Costs are defined as "consumption value" of goods and services for the creation of operational output. The use of permanent resources for production incurs costs. Depending on the extent of usage, we generally distinguish:

Fixed costs	Variable costs
(non-usage-based)	(usage-based)

The distinction is made on how costs are evolving under increasing or decreasing extent of use (depending on the workload). If the costs are changing with different extent of usage, they are called variable costs.

Example for variable costs: When a tractor with 80 kW is used for 1 hour, it consumes for example 11 liters of diesel. When it is used for 2 hours, it consumes 22 liters - the cost increases depending on the extent of use: they are changing = variable.

On the other hand, there are costs that don’t change with the extent of usage. An example is the tax for a motor vehicle. Regardless of the kilometers driven, the taxes are the same or "fixed". They are fixed costs.

The following chart shows which types of costs for the various resources are commonly occurring.

Chart 1: Outline of the costs for permanent resources

	Land	Melioration	Permanent crops	Buildings	Machinery. equipment
Fixed costs (non-usage-based):					
- Depreciation (in case of below-threshold usage of machinery, equipment)	1)	(X)	X X	X	(X)
- Claim for interest (financial costs)	X	X	(X)	X	X X
- Insurance, taxes, fees, if applicable,	X			X	X
- Accommodation (of machinery / equipment), if necessary			X		
- Upkeep, maintenance of buildings, Meliorations, permanent crops		X		X	
Variable costs (usage-based):					
- Repairs (for buildings usually added to the fixed costs)				(X)	X
- Maintenance (often added to the overhead costs of the company)					(X)
- Operating supplies (gasoline, oil, electricity, consumables, auxiliary materials)					X
- Depreciation (in case of above-threshold usage of machinery)					(X)

1) since no loss of value is occurring, there is no depreciation

Note: References in the text to guidance issued by the Kuratoriums für Technik und Bauwesen in der Landwirtschaft (KTBL) are referring to the following publications: Taschenbuch Landwirtschaft, Datensammlung Betriebsplanung, (www.ktbl.de)

1.2 Deductions for depreciation (depreciation, amortization)

From an economic standpoint, the payment of the price for the purchase of an asset doesn't constitute a cost - after all, financial assets are only converted into tangible assets.

The buyer is neither richer nor poorer after the purchase - his total assets have not changed. Costs for an asset only arise, if it is losing value by its use over time (wear).

For all depreciable equipment, the decreasing value is reflected year by year in the balance sheet, to the effect that the respective book value of an asset is continuously decreasing.

In accounting the annual amount of decreased value is called "tax depreciation" (= depreciation). Often in practice, the tax depreciation is simply referred to as "depreciation", even though the term depreciation is actually more broadly defined, and also includes decreasing values of other kinds (which are not due to wear).

Note: For resources which do not lose any value over the period of their use (such as land) no depreciation is incurred.

For residual value = 0 €:

Considering the entire life of an asset, and assuming that at the end of its operating life, the asset has no longer a market value, then its complete purchasing price has to be "written off" over the period of its use.

For residual value > 0 €:

If at the end of its operating life, the asset still has a residual value, the depreciation is only as high as the difference between the purchase price and the residual value. In case there are demolition or disposal costs emerging at the end of an asset's operating life, they are added to the purchasing/ production costs and depreciated.

Looking at the flow of money when buying an asset, a single payment is made at the point of purchase. In order to be able to replace the asset at the end of its operating life with a new one, money must be re-generated at least to the level of the total depreciation throughout the operating life. Thus, the annual write-offs represent a form of "savings" of funds for the replacement.

At this point it is not considered that, through inflation, the replacement of the asset might require any more money than the initial purchase.

The interpretation of depreciation as "saving of funds" is particularly important for the planning of operations, because the question ...

"How much money do I have to earn each year to maintain the substance of my business?"

is answered by the total of the required write-off amounts.

Therefore in summary, various objectives are resulting for depreciation

- Designation of the appropriate book value in the accounting of the company. (Nominal maintenance of assets)
- Distribution of purchasing costs (= the total depreciation) on the operating life
- Provision of funding for the replacement investments

Looking at the loss in value of fixed assets (depreciation), the period of the operating life in which the depreciation occurs must be specified (operating life, short: N). A second limiting factor in addition to the time, is the performance reserve. This relates primarily to the provided units of production (e.g. tractor hours). Here, it is assumed that with rising repair costs, an economically viable use of a machine or a device by its performance reserve (symbol n) is also limited.

Linear depreciation

The acquisition costs of the asset are divided equally between the years of operating life.

Linear depreciation is characterized by constant annual depreciation rates. As a result, the book value of an asset is reduced in equally consistent steps (= linear).

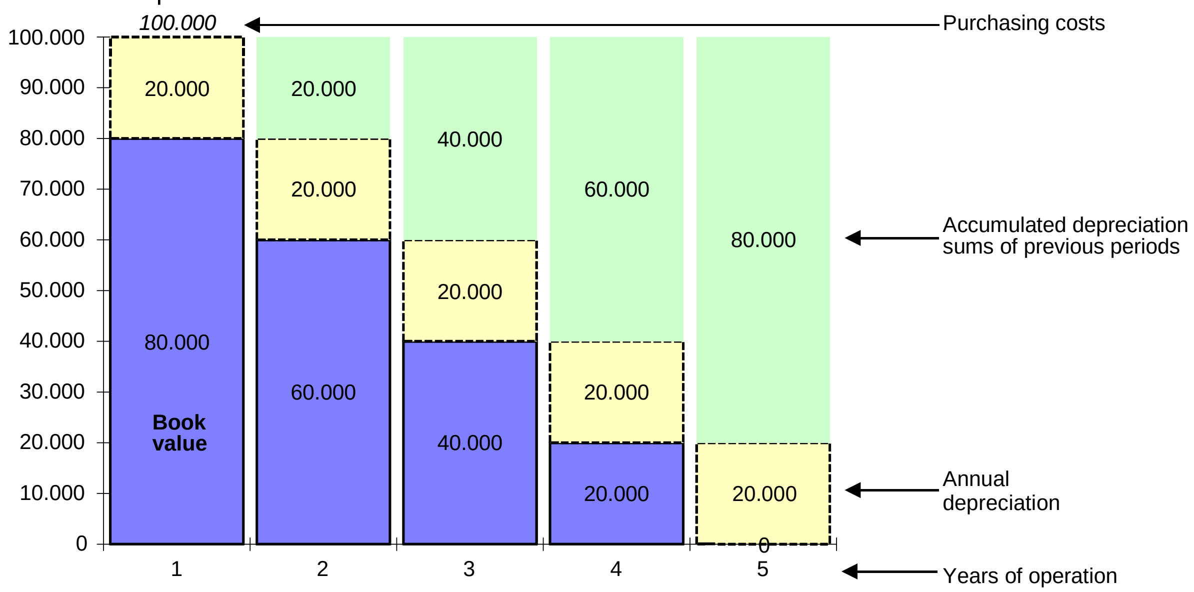
Calculation: $$\frac{\text{purchasing costs}^{1)} - \text{residual value}}{\text{(Remaining) operating life}}$$

1) possibly plus Demolition / disposal costs

Assessment:

- o Easy to calculate
- o Costs are, given an annually consistent extent of use, usually appropriately distributed over the operating life.
- o The goal of the nominal maintenance of assets is achieved (see. Replacement value amortization)
- o The goal of the real maintenance of assets is achieved only when there is no inflation assumed. However, a prerequisite for real maintenance of assets is that the actual course of value equals the book values calculated by means of linear depreciation.

Chart 2: Linear depreciation



		Year	Book value ¹	Annual Depreciatior	Previous Depreciation
Purchasing costs (A)	100.000	1	80.000	20.000	
Depreciation rate (1/ 5 yrs)	20%	2	60.000	20.000	20.000
Depreciation amount	20.000	3	40.000	20.000	40.000
		4	20.000	20.000	60.000
Book value Ø (incl. A):	50.000	5	0	20.000	80.000

1) as of the end of each financial year

1.3 Interest claim

Investment in assets binds capital. For borrowed capital, interest must be paid, equity cannot generate interest. Both varieties cause costs. These costs are expressed by the interest claim.
The interest claim includes the interest payable on borrowed capital, as well as the imputed costs for equity. The extent of the interest claim depends
- On the level of the average interest-bearing investment value and
- On the level of the rate of discount

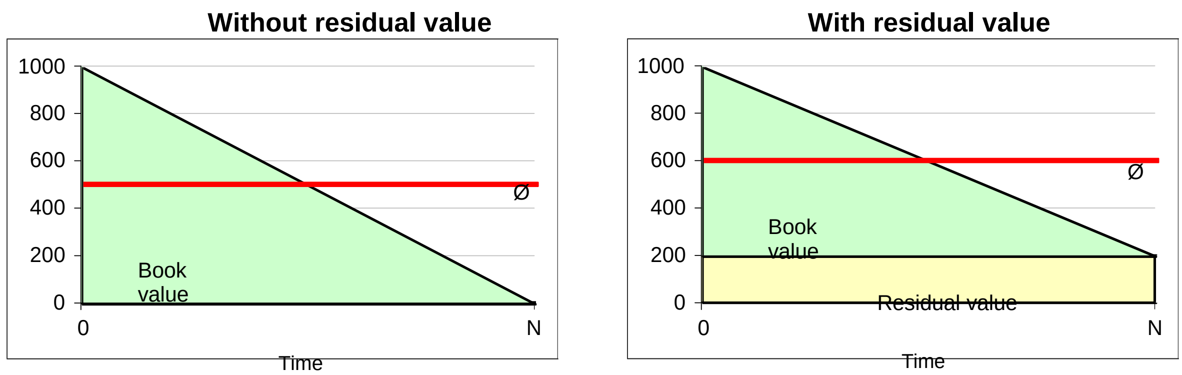
=> Interest claim = Rate of discount × Average Interest-bearing asset value over operational life
Whereas: Adequate target rate = Composite interest rate, consisting of:
Percentage of debt capital × interest rate + percentage of equity x imputed costs

1.3.1 Average interest-bearing investment value

The average interest-bearing investment value results from the average book value of each year of use (including the acquisition cost and the residual value) at the end of the operation period.
As the book values develop differently according to the method of depreciation, the chosen method will determine the level of the average interest-bearing investment value.

Assuming linear depreciation the average book value of an asset (and thus the average interest-bearing investment value), is mathematically easily determined, as the average of the value at the beginning (purchasing costs) and the value at the end (residual value).

Chart 3: Average interest-bearing investment value in % of the purchasing costs with linear depreciation



Calculation:

$$\frac{\text{Purchasing costs} - \text{Residual value}}{2} + \text{Residual value} = \frac{\text{Purchasing costs} + \text{Residual value}}{2}$$

(If the residual value equals 0, the average interest-bearing investment value amounts to: A / 2)

1.3.2 The adequate rate of discount

General rule: The rate of discount expresses the opportunity costs for the used capital. It thus represents the minimum return requirement the investor has for his investment property. The adequate rate of discount for the *total* capital is determined by the rates of discount for the invested *debt* and *equity* capital.

The adequate rate of discount for equity capital is obtained either:
- From the nominal interest income of an alternative, off-site facility/ - investment,
- From the nominal interest income of an alternative internal facility/ - investment
- From the interest savings through the repayment of debt

When making a comparison with alternative facilities/ investments, it always has to be considered that their term and risk are approximately the same.
In practice, the interest rate is often represented by a flat rate that can be achieved for capital investments ("credit interest").

The rate of discount for **borrowed capital** is measured by the interest rate that must be paid for allocated money ("loan interest rate", "borrowing rate").

If an investment is financed with **equity and debt capital**, the calculation for the rate of discount is determined by the weighted average of the discount rates of both capital shares, with the ratio being considered throughout the entire operating life.

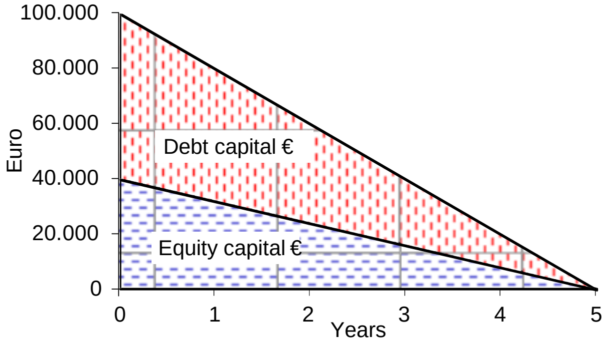
Since at this point a discussion of all possible combinations of the various forms of depreciations and loans (installment loans, annuity loan, etc.) would lead too far, the influence of financing on the discount rate should be exemplified below, using the simplest (and in practice the most important) connection of linear depreciation and linear repayment (= installment loans).
There are here two distinct cases: Case 1: Depreciation period = Repayment period
Case 2: Depreciation period > Repayment period

Case 1: Depreciation period = Repayment period
(Depreciation and repayment are linear (in equal amounts))

If (for linear depreciation and repayment) the depreciation period equals the repayment period, the ratio of debt to equity remains constant over the entire operating period. (in the following example: 60:40).

	End of the year					
	0	1	2	3	4	5
Total capital €	100.000	80.000	60.000	40.000	20.000	0
Depreciation €/a		20.000	20.000	20.000	20.000	20.000
Debt capital €	60.000	48.000	36.000	24.000	12.000	0
Repayment €/a		12.000	12.000	12.000	12.000	12.000
Equity capital €	40.000	32.000	24.000	16.000	8.000	0
Loan term:	5 years					
Operating period:	5 years					

Euro		
	Ø	%
300.000	50.000	100%
100.000	20.000	
180.000	30.000	60%
60.000	12.000	
120.000	20.000	40%



$$\text{Rate of discount} = \frac{K_e \times p_e + K_f \times p_f}{K_e + K_f}$$

K_e = Equity capital (beginning)
K_f = Debt capital (beginning)
p_e = Discount rate Equity capital
p_f = Discount rate Debt capital

The average rate of discount can therefore be easily calculated by taking the ratio of equity to debt at the beginning (time 0) as a basis, since this ratio corresponds to the average ratio for the entire operating life:

Calculation over the determined ratios:

	Capital-ratio	x	Rate of Discount	=	proportional Rate o. disc.
Equity Capital	40%	×	3%	=	1,2%
+ Debt Capital	60%	×	6%	=	3,6%
= Total Capital				=	4,8%

Alternate calculation by formula above:

$$\frac{40.000 \times 3\% + 60.000 \times 6\%}{40.000 + 60.000} = 4,8\%$$

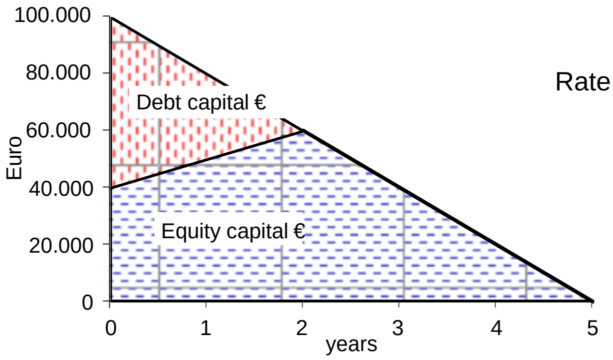
Case 2: **Depreciation period > Repayment period**

Depreciation and repayment are linear (in equal amounts)

If (for linear depreciation and repayment), the depreciation period is longer than the repayment period, the ratio of debt to equity capital changes during the operational life.

	End of the year					
	0	1	2	3	4	5
Total capital €	100.000	80.000	60.000	40.000	20.000	0
Depreciation €/a		20.000	20.000	20.000	20.000	20.000
Debt capital €	60.000	30.000	0	0	0	0
Repayment €/a		30.000	30.000	0	0	0
Equity capital €	40.000	50.000	60.000	40.000	20.000	0
Loan term:	2 years					
Operating period:	5 years					

Euro		
	Ø	%
300.000	50.000	100%
100.000	20.000	
90.000	15.000	30%
60.000	12.000	
210.000	35.000	70%



$$\text{Rate of discount} = \frac{K_e \times p_e + K_f \times p_f}{K_e + K_f}$$

K_e = Equity capital (total)

K_f = Debt capital (total)

p_e = Discount rate Equity capital

p_f = Discount rate Debt capital

The average discount rate can now, due to the initial ratio of debt to equity (time T0), no longer be calculated as the ratio changes during its operating life. Therefore, in the calculation of the capital shares the total amount of capital over the entire operating life is relevant.

Calculation over the determined ratios::

	Capital ratio	×	Rate of Discount	=	Proport. Rate o. disc
Equity capital	70%	×	3%	=	2,1%
+ Debt capital	30%	×	6%	=	1,8%
= Total capital				=	3,9%

Alternate calculation by formula

$$\frac{210.000 \times 3\% + 90.000 \times 6\%}{210.000 + 90.000} = 3{,}9\%$$

2 Cost of machinery, equipment and operational facilities

Example: Machinery: tractors, harvesters, choppers (mostly mobile, self-propelled or drawn)
Equipment: plow, harrow, cultivator, …
Operating equipment: milk refrigeration, cleaning of seeds, grist-mill, air conditioning, ...

2.1 Depreciation threshold

Concerning machinery and equipment costs, there is one distinction to be considered: write-offs can be fixed (independent of usage) or variable (usage based). This results from the fact that the operating life of equipment is limited by two factors:

a) Technical and substantial obsolescence and
b) Wear of the machine due to use.

A machine has, for example, a performance reserve of 10,000 hours and a technical and material-related operating life of 10 years. If the machine is sparsely used, that is less than 10,000 h: 10 years = 1000 h / year, then its operating life is limited by the technical and material-related aging - it will last 10 years, the loss of value is spread out over 10 years. The operating life (and therefore the depreciation) is not affected by a change in annual use, so that in this case, the depreciation is independent of use and thus considered fixed costs. However, when the annual use exceeds the threshold of 10,000 h: 10 years = 1000 h/ year, then the performance reserve of the machine of 10,000 h is consumed in less than in 10 years, i.e. it cannot be used for 10 years, but must be replaced sooner.
The operating life and therefore the depreciation are dependent on the workload per year and is therefore to be considered a variable cost. With a workload of 2,000 hours per year, the machine will be worn in 5 years, and thus must be written off in 5 years. If it is used for 2500 hours per year, in four years. Since the write-offs belong to either the fixed or the variable costs, depending on the machine's annual workload, they are called "conditionally variable costs".
The machinery costs must therefore be broken down as follows:

Machinery costs		
Fixed costs	**Conditionally variable costs**	**Variable costs**
Interest claim Accommodation Insurance Vehicle tax where appropriate *),	Depreciation	Maintenance Repairs Operating supplies Consumables, auxiliary supplies

*) no taxes are imposed in case in agricultural use

The limit at which depreciation is variable is referred to as depreciation threshold. It corresponds to the annual workload at which both the operating life in years (N) and the operating life in output (n) are used up simultaneously

$$\text{Depreciation threshold} = \frac{\text{Operating life in output (h, ha, etc)}}{\text{Operating life in years (yr.)}} = \frac{n}{N}$$

2.2 Fixed Costs

2.2.1 Depreciation (with below-threshold use)

When the workload for a machine is below the depreciation threshold (n/N) the write-offs are usage-independent and are added to the fixed costs.
In economic calculations for annual depreciation a linear approach is common (depreciation in equal rates), to achieve a uniform distribution of the cost over the operating life:

$$\text{Depreciation per year} = \frac{\text{Purchasing costs (A) – Residual value (R)}}{\text{Operating life in years (N)}}$$

Disposal costs at the end of use would be added to the purchasing costs in the depreciation calculation, but usually at most occur with stationary operating devices before and are usually neglected in practice.

Residual value and operating life
In the calculation of depreciation, net book values and operating lives play important roles. If a <u>residual value</u> is set, the results are lower depreciation and higher interest claim.
To avoid calculating the cost too low, a residual value should be set only if the intended operating life is significantly below the usual/ possible operating life and if the machine can actually expect this resale value after usage. This is usually the case for tractors and self-propelled vehicles (combine harvester, forage harvester).
When determining the operating life, it is important to note that not the possible technical lifetime is relevant for the calculation of depreciation, but the expected operating life. During this period, the loss in value again must be earned back.
It rarely makes sense to write a machine off over more than 15 years, even though there are many machines with low level workload still in use after 20 years or more.
Standard values such as for repair costs as specified in KTBL are all based on standard operating lives. When machines are used for longer, the repair costs often rise above these standard values.
A long operating life (= low depreciation) and the possible neglect of higher repair costs can lead to underestimation of the costs. This should be avoided.
By making a conscious over assessment of the depreciation, a rather cautious (shorter) determination of the operating life prevents that the higher repair costs at a higher age are “forgotten”,

2.2.2 Interest claim

In case of linear depreciation the interest claim is calculated taking 50% of the sum of the purchasing/ production costs and residual value, multiplied by the discount rate.
$((A + R) / 2) \times$ Discount rate
For further details see point 1.3

2.2.3 Accommodation

The costs for accommodation include variable and fixed costs for machine shed and storage shed. The total costs per year are then apportioned to the space requirements of the machine/ device. Since it is very elaborate to gather the exact numbers, accommodation costs are often simply estimated at 0.5% to 1% of the machine's purchasing costs in practical calculation.
It is more precise however, to estimate the accommodation costs for machines by their footprint and space requirements.
In its publication "Betriebsplanung Landwirtschaft (2012-13)", the KTBL has designated the following reference values for garages and storage sheds:

Investment needs and annual building costs for garages
Garage: steel frame construction,
Walls: Steel panels,
Roofing: Fiber cement corrugated panel

	Length / width	Base area	Usable space	Investment need		Annual costs	
	m	m^2	m^2	€ total	€/m²	€ total[1)]	€/m²
Shed, one side open, interlocked pavers	31,25/13	406,25	397	68.391	172,27	4.572	**11,52**
Fully enclosed, 3 sectional doors	30/15	450	441	94.784	214,93	6.369	**14,44**
Interlocked pavers	42/22,5	945	933	195.474	209,51	13.292	14,25
Fully enclosed, 4 sectional doors Floor panels in reinforced concrete	60/25	1500	1483	339.803	229,13	22.937	**15,47**

Source: KTBL "Betriebsplanung Landwirtschaft (agricultural operational planning) 2012/13 23, 2012 edition, Darmstadt

1) Total depreciation, interest expense, maintenance and insurance
Depreciation: operating life for long / medium / short-term components 30/ 15/ 10 years. Interest claim: discount rate of 4%
Maintenance: Repair costs of long / medium / short-term components 1/ 2/ 3 % of investment needs.
Insurance: 0.2% of the investment needs

The costs per m² are referring to the base area at 4 m usable height of the building. The machine's footprint can be calculated as follows:
(Length of the machine in m + 1.20 m) x (width of the machine in m + 1.20 m).

Example 80 kW four-wheel-drive tractor:
Length: 4.70 m + 1.20 m = 5.90 m
Width: 2.50 m + 1.20 m = 3.70 m
Floor space requirements: 21.83 m2

Examples:	Req. floor space			Gross costs per year		
Tractor, 80 kW (5m x 2.4m) (enclosed, reinforced concrete floor)	21,83 m²	×	**15,47** €/m²	=	337,6 €/ year
Turning plow, 5-shard (enclosed, interlocked paving)	*11,27* m²	×	**14,44** €/m²	=	162,8 €/ year
Tandem trailer 10t (Shed, interlocked paving)	*14,88* m²	×	**11,52** €/m²	=	171,4 €/ year

Comparison:
Assuming a 80 kW, four-wheel-drive tractor has a purchasing price of 69,000 € and a footprint of 22.83 m² and is placed as described above, in a fully enclosed garage with reinforced floor, sectional doors then annual accommodation costs of 337.60 € can be charged.
With the flat-rate approach of 0.5% to 1.0% of the purchasing price, the accommodation costs would amount to 345 € at 0.5%, and 690 € at 1%.

Alternatively to a calculation based on the construction costs, an approach in form of a rental payment is possible, provided that the relevant information is available.

2.2.4 Insurance, taxes, fees

Insurance: All costs incurred for the statutory or voluntary insurance are listed.

The KTBL assesses for tractors and self-propelled machines the following annual insurance costs (Liability insurance) (2012, Operational agriculture p 57):

Tractor	45 - 55 kW	215 € / year
Tractor	55-74 kW	275 € / year
Tractor	> 74 kW	approx. 405 € / year
Self-propelled harvesters (example combine harvester)		60 € / year

In practice, the annual insurance costs are often simply estimated at a flat rate of 1% of the purchasing costs. Compared to the values in KTBL this estimation is rather too high. From the KTBL data, the following rates can be deduced:

- Four-wheel tractors approximately 0.45% of the acquisition costs (from 0.3 to 0.6%)
- Self-propelled (also combine harvester) approximately 0.25% of the acquisition cost (0,2 - 0,3%)

Taxation: All costs for the direct taxation of an asset.

In the Federal Republic of Germany, agricultural vehicles are exempt from the motor vehicle tax, therefore no taxes have to be included.

Fees: Technical supervision of vehicles with their own license plate.

Maximum permissible mass (t)	General inspection		Safety check	
	Interval*	Costs (€)	Interval*	Costs (€)
Up to 3,5 t **)	24	40		25
> 3,5 to 7,5 t	12	50		45
> 7,5 to 12 t	12	60	6 ***)	55
> 12 to 18 t	12	70	6	60
> 18 to 32 t	12	80	6	70
> 32 t	12	90	6	80

*) interval in months

**) As well as vehicles with structurally determinded maximum speed of 40 km/h

***) for trailers starting from 10 t

Source: KTBL Betriebsplanung Landwirtschaft 2012/2013

For crop protection equipment a regular, (bi-annual) inspection is mandatory in the Federal Republic of Germany.

The KTBL has assessed an amount of 4 € per each meter of working width.

2.2.5 Practice-Tipp

As stated above, not only depreciation and interest claims, but for reasons of simplification also, the annual costs of accommodation and insurance are measured according to the purchasing costs (A) of a machine.

Depreciation:	Depending on operational life	8% - 12% of A
Interest claim:	Depending on financing: 4% to 10% of A/2	2% - 5% of A
Accommodation:	Garage, flat-rate	1% of A
Insurance, etc.:	For tractors and self-propelled vehicles, flat-rate	1% of A
Total of annual fixed costs:		**12% - 19% of A**

2.3 Variable Costs

2.3.1 Depreciation (at above-threshold use)

If a machine is used above its depreciation threshold (N/ n), then it is called above-threshold wear. The machine is stressed more, and the performance reserve before the end of the operating life is depleted. The level of costs now depends on the specific workload.
Upon above-threshold use the depreciation of machines is a variable cost factor. The amount of write-offs for each unit-of-production (h, ha, etc.) is determined by:

$$\text{Depreciation in unit-of-production (h, ha, etc.)} = \frac{\text{Purchasing costs (A) - Residual value (R)}}{\text{Performance reserve (h, ha, etc.)}}$$

The depreciation per year is the product of depreciation in unit-of-production, times the performance units per year.

2.3.2 Repairs

The determination of the cost of repair poses a significant problem with the calculation of machinery costs. The general practice of “as much practical data as possible and as little standard data as necessary” is not recommended in this case. With the use of individual company records, the problem arises, that in order to determine the repair costs correctly, all types of repairs over the entire lifetime of a machine must be recorded and attributed accordingly. However, since in practice all records over the entire operating life of a machine are hardly available for identical machines, it is (even for large enterprises) recommended to rely on standard data.
Additionally, when relying on empirical values, opportunity costs for own repair work (imputed wage costs), are often completely ignored.

In the Federal Republic of Germany, the KTBL issues standard values for the repair costs of machinery which are constantly updated (Taschenbuch Landwirtschaft, Datensammlung Betriebsplanung, www.ktbl.de).
Reports from agricultural enterprises and service providers serve as the predominant source of data for actually incurred repairs and maintenance work.
This also includes wear of tires and the labor costs for own repair work. From the large amount of data, it is possible to estimate the expected average pattern of the repair costs.

The following factors play an important role in assessing the repair costs:
- Age and use of the machine,
- Maintenance and preventive servicing,
- Structure and functions of individual units, percentage of wear parts.
- Driver

The standard values of KTBL always refer to one unit-of-production (i.e. costs per ha, h, etc.) and are always considered average for the entire "working and operating life period of a machine", i.e. from the purchase of a new machine until the end of the operating life that is determined in performance units (h, ha, etc).

> Example: The performance reserve (the operating life in performance units) for a 4-wheel-drive tractor is 10.000 hours. At full capacity, i.e. when the tractor actually reaches 10,000 operating hours the repair costs guideline value is an average of 5 € per hour.

With a workload less than the potential use of a machine, there are also lower average repair costs expected per unit of usage.
With purchase of used equipment on the other hand, there are higher average repair costs to be expected, since the susceptibility to repair increases considerably with increasing age (and usage) and the initial time of less repairs is already over.

In order to give adequate consideration to the two factors
- End of usage before reaching the end of capacity (low workload) and
- Beginning of usage when already a part of the performance reserve has been consumed ("second-hand machine")

KTBL has developed correction factors.

These correction factors distinguish between machines and equipment that have high or low regular wear. For example, plows usually have a comparatively high and consistent wear due to the heavy load during operation. In contrast, for example, tractors have a more "cyclical" wear (repairs often occur after a more or less prolonged "repair free" time). In the first case, the repairs rise on average less than machines with an initially lower regular wear.
The initial value is always the factor 1, which represents a new machine at 100% utilization.

Chart 4: Repair cost correction factors

4.1 Machines with low wear (tractors, self-propelled machines, transportation)										
Age in	End of operating life of the machine in % of n									
% of n	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
New	0,32	0,45	0,56	0,64	0,72	0,78	0,85	0,90	0,96	1,00
10%		0,58	0,66	0,74	0,80	0,87	0,92	0,98	1,03	1,08
20%			0,75	0,82	0,88	0,94	0,99	1,04	1,09	1,14
30%				0,89	0,95	1,00	1,05	1,10	1,15	1,19
40%					1,01	1,06	1,11	1,16	1,20	1,25
50%						1,11	1,16	1,21	1,25	1,29
60%							1,21	1,25	1,30	1,34
70%								1,30	1,34	1,38
80%									1,38	1,42
90%										1,46

4.2 Machines with high wear (tillage, harvest)										
Age in	End of operating life of the machine in % of n									
% of n	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
new	0,45	0,58	0,67	0,74	0,80	0,85	0,89	0,94	0,97	1,00
10%		0,69	0,76	0,82	0,87	0,91	0,96	0,99	1,03	1,06
20%			0,83	0,88	0,93	0,97	1,01	1,04	1,08	1,11
30%				0,93	0,98	1,02	1,05	1,09	1,12	1,15
40%					1,02	1,06	1,09	1,12	1,15	1,18
50%						1,09	1,13	1,16	1,19	1,22
60%							1,16	1,19	1,22	1,25
70%								1,22	1,25	1,27
80%									1,28	1,30
90%										1,33

n = total operating life of the machine in performance (in km, operating hours, etc.)

Source: Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL): Betriebsplanung Landwirtschaft, 2012.

Example:

The performance reserve (i.e. the operating life in performance) for a four-wheel-drive tractor is 10,000 hours (in max. 12 years). Assumed a tractor is purchased new and the entire performance reserve is retrieved, which means it is used for 10,000 h, then the entire repair costs of 50,000 €, or an average of 5.00 € per hour have to be considered.

If the tractor is used less, the total costs of repairs as well as the average repair costs are declining. Based on the cost of repairs at full capacity (in the example 5,- €) the costs of repairs are now calculated according to the lower utilization at a lower level, due to the correction factor.
If the engine is utilized only at 80% (i.e. only 8000 hours of total performance or 8,000 / 12 years = 667 hours per year), the correction factor is 0.90 (see chart 4.1).
Consequently, the average repair costs are:

0,90 × 5,00 €/ h = 4,50 €/ hour

If the tractor is not new but has already used up 30% of its performance reserve (i.e. has already performed for 3000 hours) the correction factor for the remaining operating life is:
- If the tractor is used for another 7,000 hours until the 10,000 hours are reached:

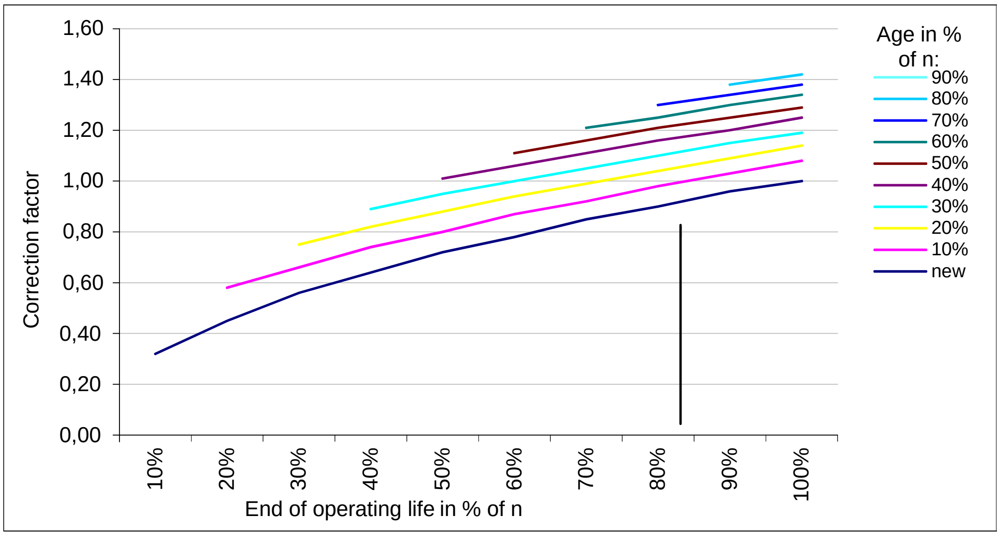
1,19 × 5,00 €/ hour = 5.95 €/ hour

- If the tractor is only used for another 5,000 hours until 8,000 hours are reached:

1,10 × 5,00 € / hour = 5.50 €/ hour

chart table shows the correction factors for the repair costs as a graph, exemplified for machines with low wear:

Chart 5: Trend lines of repair cost correction factors
for machines with low regular wear



The graph makes the non-linear course of the repair costs depending on age and utilization of a machine particularly clear.
For new machines, the trend lines follow a course that approximately corresponds to the following functions:

- Machines with low wear: Correction factor = workload in % ^{0,5}
- Machines with high wear: Correction factor = workload in % ^{0,35}

Example: Correction factor for a new plow with a workload of von 67%:
Correction factor = workload in % ^{0,35} = 67% ^{0,35} = 0,67 ^{0,35} = 0,869

2.3.3 Maintenance

The maintenance of machinery contributes significantly to the maintenance of the value. It requires primarily work time. The costs of materials (especially greases and oils) are low and part of the fuel costs.
Since the maintenance is for the most part carried out during periods of low workload (primarily in winter time), the opportunity costs for the expended work are low.
Maintenance costs are usually not attributed to the machinery costs, but rather recorded within the general farm work and attributed to the (fixed) overhead costs of the operation.

2.3.4 Operating supplies, consumables, auxiliary supplies

The operating supply costs include:
- Energy costs for the operation of combustion engines and electric motors
- Costs for lubricants to reduce wear
- Auxiliary supply costs (summary of other consumables such as twine, plastics etc.)

The amount of fuel costs depends on the required quantity and the price.

Example: 20 liters consumption of diesel fuel per hour × 1.13 €/ liter = 22.60 €/ hour

When determining the fuel price it is important to consider:

- “Gasölverbilligung” (gas subsidy): In Germany, farmers get a portion of the fuel costs subsequently reimbursed by the state (in 2014: 0.2148 €/ l). This rebate must be included in the price calculation (price 1.35 €/ l - 0.2148 €/ l = 1.132 €/ l).

Standard values for fuel consumption are published by KTBL. They apply at medium engine load. For work at an engine load clearly lower or higher, the consumption can be decreased by up to 30% (e.g. during swath raking) or increased to up to 50% (for example during deep plowing).
Rule of thumb for medium engine load: 0.1 liters of diesel per hp and hour (0,136 liters per kW and hour) The lubricant oil consumption is usually estimated at 1% of the diesel consumption.

2.4 Exemplary machine cost calculations

New machines

The following chart helps determine the variable and fixed costs of a new machine, shown in both "above-threshold" as well as "below-threshold" use.

Chart 6: Machinery cost calculation for a new 4 wheel-drive tractor (85 kW)

Purchasing costs (A)			**69.000**	**€**
Residual value (R)			**0**	**€**
Operational life in years (N)			**12**	**yr.**
Operational life in performance (n)			**10.000**	**h**
Depreciation threshold (n / N)			**833**	**h/yr**
Rate of Discount (p)			**4,8**	**%**
Insurance (flat-rate)			**0,45**	**% of A**
Accommodation (flat-rate)			**0,75**	**% of A**
Standard values for repair costs				
At a total 10.000 h	100% workload			7,00 €/h
At a total 7.200 h	72% workload	correction factor 0,891		6,24 €/h
Operating supplies				
Diesel	10 l / h ×	1,13 € / l =	11,30 € / h	
Lubricant oils (flat-rate 1% of Diesel consumption)	0,1 l / h ×	2,32 € / l =	0,23 € / h	

Annual workload		**h**	**600**	**1200**
FIXED COSTS				
Depreciation	(A – R) / N	€/ yr	5.750,00	0,00
		€/h	9,58	0,00
Interest claim	(A + R) / 2 × p	€/ yr	1.656,00	1.656,00
		€/h	2,76	1,38
Insurance	0,45 % of A	€/ yr	310,50	310,50
		€/h	0,52	0,26
Accommodation	0,75 % of A	€/ yr	517,50	517,50
		€/h	0,86	0,43
Total fixed costs	**per year**	**€/ yr**	**8.234,00**	**2.484,00**
	Per h	**€/h**	**13,72**	**2,07**
VARIABLE COSTS				
Depreciation	(A – R) / n	€/h	0,00	6,90
		€/ yr	0,00	8.280,00
Repair costs		€/h	6,24	7,00
		€/ yr	3.743,83	8.400,00
Operating supply costs		€/h	11,53	11,53
(Diesel + lubricant oils)		€/ yr	6.919,20	13.838,40
Total variable costs	**per h**	**€/h**	**17,77**	**25,43**
	per year	**€/ yr**	**10.663,03**	**30.518,40**
TOTAL COSTS 1) 2)				
Total costs	**per year**	**€/yr**	**18.897,03**	**33.002,40**
(Variable + Fixed costs)	**per h**	**€/h**	**31,50**	**27,50**

1) Maintenance costs were not included. Their extent is significantly determined by the evaluation of the working time (labor costs or opportunity costs).

2) All prices are net.

Used Equipment

The calculation of the costs for used machines is analogous to the calculation for new machines. Depreciation is calculated on the basis of the remaining operating life and the purchasing costs (incurred when buying a used machine).
If the calculation is for the continued use of an existing machine, it should be noted that the actual market value must be used as a calculating basis for depreciation and interest claim instead of the (purely theoretical) book value.
The standard value for repair costs has to be corrected (valid for the total performance reserve n) according to the already consumed and still expected performance (factor according to chart 4)

Chart 7: Machinery cost calculation for a used combine harvester
3,9 m working width; 147 kW, Output 1,5 h/ha, all prices net

Purchasing costs (resp. market value of prev. harvester)	59.000 €	
Original price (for comparison)	165.000 €	
Book value (in case of an existing harvester)	1 €	
Rate of discount	4,80 %	
Output area	1,32 ha/h	
Total operating life (N)	12 yr.	
Previously consumed operating life (of N)	8 yr.	
Remaining operating life of harvester (N_{rest})	4 yr.	
Total operating life in performance (n)	3.000 h	
Previously consumed performance (von n):	1.800 h =	60% of n
Annual workload for the remaining operating life:	150 h =	198 ha
Expected end of operating life at:	2.400 h =	80% of n

Repairs:	on average for total performance				11,00 €/h	
	For remaining usage from 62% to 80% of n				12,76 €/h	(Factor: 1,16
Operating supplies:	Diesel	27,3 l/ h ×	1,13 €/ l	=	30,85 €/h	
	Lubricant oil	0,273 l/ h ×	2,32 €/ l	=	0,63 €/h	

Losses compared to a new harvester / or service contractor [1)] 10,00 €/ha (= 1 dt grain per ha)

Fixed costs		
Depreciation	14.750 €/ yr.	
Interest claim	1.416 €/ yr.	
Fixed costs per year	16.166 €/ yr.	
Fixed costs per ha	107,77 €/h	82 €/ha
Variable costs		
Repairs	12,76 €/h	9,67 €/ha
Operating supplies	31,48 €/h	23,85 €/ha
Variable costs per ha	44,24 €/h	33,52 €/ha
Variable costs per year	6.636 €/yr.	
Total costs		
Total costs per year	16.166 €/yr	
Total costs per ha	152,02 €/h	115,16 €/ha
Losses per ha	13,20 €/h	10,00 €/ha
(Comparative -)[1)] Costs per ha for the current combine	165,22 €/h	125,16 €/ha

1) see chapter 2.5

2.5 Procedural costs, comparative costs und minimum workload

2.5.1 Procedural costs

The Procedural costs include all costs incurred for the implementation of a work process.

For example, plowing of 1 ha: tractor costs + total cost for plow + wage claim.
In this case the tractor costs can only be recognized as variable costs, if it can be assumed that the tractor is already present. If the tractor is only used for a single work process, the fixed costs also have to be taken into account.
The opportunity costs of work are usually difficult to determine. It is therefore often based on the wage costs for seasonal workers.

Procedural costs = Machinery costs + labor costs
Machinery costs per ha or hour of operation
Attributable fixed costs of the machine (for example plow)
Attributable fixed costs for the tractor
variable costs for the machine
variable costs for the tractor
+ Labor costs per ha or working hour:
Opportunity costs for man-hours of permanent family workers
Wages / Opportunity costs for man-hours pf permanent laborers
Wages for non-permanent laborers
= **Procedural costs**

2.5.2 Comparative costs

The excellence of alternatively usable methods can usually not be determined solely on the basis of the procedural costs, because the technical level of the equipment, the quality of work etc. may show strong differences.
The following applies: Comparative costs = Procedural costs ± additions/ deductions for labor quality, etc.
For additions/ deductions, the following parameters are relevant:

- *Speeding costs*: Although increased operating speed enhances the area output, it decreases the quality of work, yield losses occur.
- *Timeliness costs*: with increasing output area, the finishing point for the work diverges more and more from the optimal time, and losses can occur.
- *Technical progress*: can possibly cause lower losses or
- *Different man-hour demand*

Important: Depending on the situation, the positions can adversely affect both the owned as well rented machinery and equipment.

2.5.3 Minimum workload for machines

When comparing external and internal mechanization, the decision about which one is the better of the two alternatives is depending decisively on the workload (annual extent of utilization) of the owned machine. With increasing use of own machine, the burden of fixed costs per service unit (ha, h, etc) decreases, whereby its competitive position versus the external mechanization is improved.
It is now to be determined, which workload (ha, h., etc.) a machine must achieve per year, so the costs for internal mechanization are lower than the costs of external mechanization. Therefore, we compare the costs of the owned machine on the one hand, with the cost of the rental machine on the other hand. The variable in this equation is the workload of the owned machine, which ultimately determines the level of the fixed cost burden per ha or h. This way it is determined, at which workload there is cost equality between the two alternatives.

bekannt

$$\frac{\text{Fixed costs per year}}{\text{Workload (ha od. h)}} + \text{Variable costs per ha or h} = \text{Costs rental machine per ha or h}$$

Unknown variable

Rearranging the equation and solving for the variable "extent of utilization" results in:

$$\text{(Minimum-) Extent of utilization} = \frac{\text{Fixed costs of owned machine per year}}{\underset{\text{per ha or h}}{\text{Costs rental machine}} - \underset{\text{per ha or h}}{\text{Variable machinery costs owned machine}}}$$

Ex. Should a turning plow be leased or bought?

Cost of rental machine:	Billing rate:	30 € per ha	(Billing rates for Baden-Wuerttemberg.- 2011-2012, Machinery cooperative)
Cost of owned machine:	Fixed costs:	2800 € per year	KTBL, MaKo, 2014
	Variable Costs:	12 € per ha	KTBL, MaKo, 2014

$$\frac{2800}{X \text{ ha}} + 12 = 30 \qquad X = \frac{2789}{30 - 12} = 155 \text{ ha}$$

At a workload of 155 ha per year is cost equality
At a workload of > 155 ha per year the owned plow is cheaper
At a workload of < 155 ha per year the leased plow is cheaper

When it comes to the comparison of entire work processes (as described in section 2.5.1), the costs of all elements involved need to be taken into account: equipment, tractor, work. In cases when there are differences between internal and external mechanization in terms of the quality of work, the expected disadvantages (speeding costs, timeliness costs etc.) have to be attributed as costs to the relevant side.

$$\text{(Minimum-) Extent of utilization} = \frac{\text{Fixed costs of owned machinery per year}}{\underset{\text{per ha or yr.}}{\text{Costs of provided services}} - \underset{\text{addl. Tr-h} \times \text{Tr-C, MHR} \times \text{LA}}{\text{VC owned machine per ha / h}}}$$

in addition, timeliness costs, speeding costs, etc. as long as they are a disadvantage to external mechanization

in addition, timeliness costs, speeding costs, etc. as long as they are a disadvantage to internal mechanization

VK = Variable machinery costs of owned machinery
MHR × LA = Man hours × imputed wages (additional costs for man hours in case of internal mechanization)
Tr-h × Tr-C = Tractor hours × var. Tractor costs (additional tractor costs with internal mechanization)