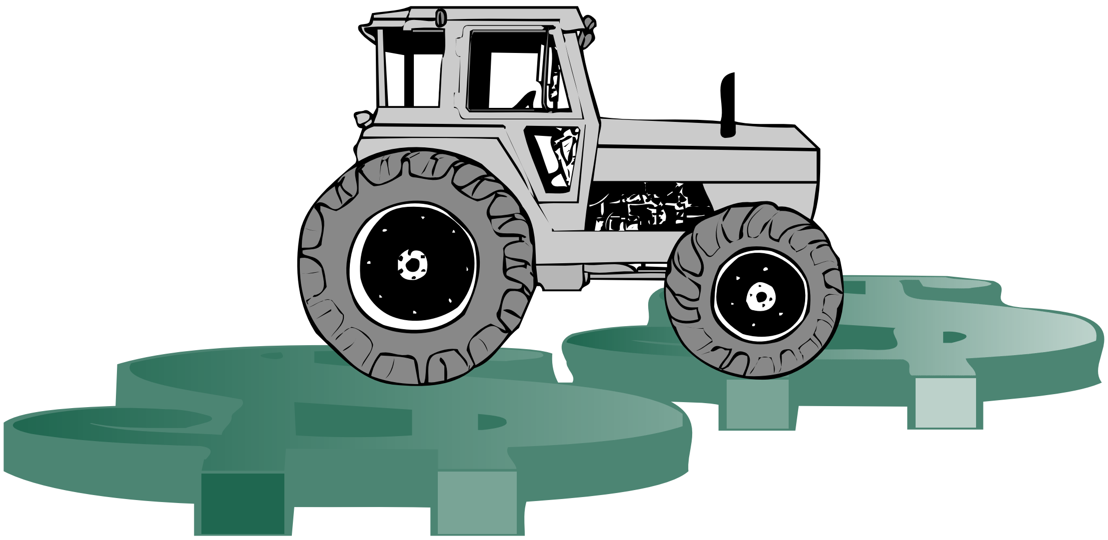
Farm Machinery Operation Cost Calculations



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Abbreviations Used in this Publication

AC	Allis Chalmers Gleaner
AGE	Machine's age in years
AH	Accumulated Hours on a Machine
APH	Acres per Hour
ARM	Accumulated Repair and Maintenance Charges
ASAE	American Society of Agricultural Engineers
BTBASIS	Beginning Tax Basis at the Time of Purchase
CF	Cash Flow
CLP	Current List Price
COC	Cost of Capital Rate
dep1, dep2	Depreciation Factors
DFCF	Tax Deductable Financing Cash Flow
EUL	Estimated Useful Life
FEP	Field Efficiency Percentage
FL	Fuel and Lubrication Charges
FS	Field Speed
GAIN	Selling Price Less Tax Basis
HPY	Average Hours per Year of machine usage since it was new
IAACF	Inflation Adjusted Amortized Annual Cash Flow
IH	International Harvester
ITS	Income Tax Savings
LAB	Annual Labor Charges
MACRS	Modified Accelerated Cost Recovery System
MF	Massey Ferguson
MV	Market Value
MW	Machine Width
NDFCF	Nondeductible Financing Cash Flow
NH	New Holland
NPV	Net Present Value
PPI	Producer Price Index
PUR	Purchase Price
RAF	Repair Adjustment Factor
RF1, RF2	Repair Factors
RM	Repair and Maintenance Charge for a Specific Year
RVP	Remaining Value Percentage
SE	Net Self-employment Tax Rate
SEC179	Section 179 Expense Deduction
SELL	Selling Price
T1	Federal and State Income Tax Rate
T2	Federal and State Income Tax Rate, Including Self-employment Tax Rate
TBASIS	Remaining Tax Basis in any Given Year
TDEPR	Tax Depreciation in a Given Year
TIS	Property Taxes, Insurance, and Shelter

Machinery operating and ownership costs are often more than half of total crop production costs for Kansas producers and substantially affect farm profitability. Besides affecting fundamental machinery buying and trading decisions, machinery costs affect profit-maximizing crop and rotation selection, thus long-run farm profitability. Understanding machinery costs becomes especially crucial when considering alternative cropping systems, particularly when less tillage is involved. In short, machinery costs enter farm management in three areas: 1) minimizing costs of production, 2) selecting the profit-maximizing crop mix, and 3) considering structural or technological changes, such as farm expansion or contraction, or alternative tillage systems.

Minimizing the machinery portion of production costs requires routine assessment of the benefits and costs associated with owning, leasing, or renting machinery. These must regularly be compared with hiring machinery operations (custom farming), which is often a plausible alternative. To assist farm managers in machinery decisions, this bulletin develops a framework for calculating and analyzing the various components of a machine's expected annual costs: repairs and maintenance; gas, fuel, and oil; operating labor; insurance and taxes; depreciation; and opportunity cost on funds used.

For crop enterprise selection, machinery costs must be assigned to specific crops or crop sequences. Actual historical machine costs can provide a basis for such assignments but may be difficult to obtain. That is, some costs associated with machinery operations are difficult to allocate to the usage of specific machines. However, because producers can identify each machine and the number of its operations associated with a crop, a framework for calculating a machine's expected costs can assist in developing crop-specific machinery costs.

Machinery costs are especially important when considering structural or technological changes. For example, recently acquired rented land, requiring additional machinery, may be unavailable in the future. An experiment in no-till farming, requiring less machinery, may turn out to be unprofitable. In such cases, inherent risks may cause a producer to make the change while retaining the pre-existing machinery line. Understanding how machinery costs are affected by intensity of machine use is crucial to such decisions. Thus, methods for analyzing machinery costs should be detailed enough to deal with such issues.

Machinery investment analysis is more complex than dealing with annual cash inputs, such as seed or fertilizer, because benefits and costs accrue over a number of years. That is, each machine operation is associated with a stream of cash outflows/inflows over time. Income tax rates, interest rates, depreciation rates, and inflation rates affect the cash flows. The goal in machinery cost analysis is to provide a framework for combining net cash flows for several machine operations, or machinery services, into a single annual value. In that way, the annual machinery costs associated with one cropping/tillage scenario can be directly compared with those from another scenario, or with custom farming charges.

Comparison of simulated machinery costs with custom farming charges is not only important because custom farming is a competing source of machinery operations, but also because custom rates can be used to validate simulated costs. This follows because custom rates are market-based. Further, because they are readily available, custom rates provide an inexpensive proxy for actual machinery costs in the absence of more reliable information.[1] Nonetheless, custom rates provide a poor proxy in analyzing structural or technological farm changes such as those already noted. These situations demand the more detailed machinery ownership costs analysis framework developed here.

Fundamental to understanding machinery ownership costs is an understanding of how machinery is valued over time. This topic is covered in the first section of this bulletin. The second section covers traditional annual operating costs such as fuel and labor. The third section introduces income taxes and finance.

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[1] *One readily available publication providing custom farming rates in Kansas on a regional basis is "Custom Rates", published annually by Kansas Dept. of Agriculture, Kansas Agricultural Statistics (address: Agricultural Statistician, P.O. Box 3534, Topeka, Kansas, 66601-3534).*

To expedite understanding, concepts are presented in both words and in mathematical formulas with numerical examples. The order of presentation facilitates the mathematical development of the formulas as they would need to evolve if placed in a computer spreadsheet.

Valuing Machinery Over Time

Analysis Time Period

A machinery or machine operation cost analysis takes place at a specific point in time. However, because it regularly involves capital investment (as in purchased machines), the analysis covers some fixed amount of time into the future, for example 10 years.[2] We assume this analysis is occurring around the end of 1996, while planning for machine operations in 1997 and beyond. Any machinery considered purchased is assumed purchased in 1996 (year 0). However, it is not used until 1997 (year 1). A 10-year analysis (including 10 harvests) would end following the fall harvest in 2006 (year 10). Variables are subscripted as needed with either an n (1996, 1997, …) or a k (0,1, …) to facilitate tracking in a spreadsheet setting. The symbols *begin* and *end* refer to beginning and ending years in an analysis, respectively (depending upon whether n or k is used to denote years, *begin* = 1996 or *begin* = 0; likewise, a 10-year study is associated with either *end* = 2006 or *end* = 10).

Current List Price

A new machine rarely sells at its list price. Rather, it sells around 80 to 90 percent of list (Bowers, 1994). Because machinery list prices are more readily available than prices paid, research has often been conducted on that basis, leading certain formulas to depend on list price. A current list price needs to be established whether the machine is new or used. For a new machine today, current list price is today's list price. For a used machine today, current list price is the value at which an identical machine would be listed today, if it were new.

One way to establish the current list price (in 1996) for a 1991 John Deere Model 9600 combine is to observe the list price at a John Deere dealer today (1996) for a 1996 John Deere Model 9600 combine.[3] That value is the current list price for the 1991 used combine. However, the 1996 combine often contains technologically-improved features over the 1991 model. Thus, it may not be identical to the 1991 model. Furthermore, models manufactured in the past may have been discontinued. In such cases, using today's list price to represent the current list price of a used machine may be inappropriate.

A second, and often more appropriate method for establishing current list price (in 1996) for the 1991 John Deere combine is to directly adjust the original list price of the combine in 1991 by a suitable measure of price inflation occurring between 1991 and 1996. A commonly used measure of price inflation for agriculture is the producer price index.

Producer Price Index[4]

Table 1 provides historical producer price index (PPI) values. It also provides annual inflation rates, which can be computed from successive PPI values according to: inflation (i) = $(PPI_n \div PPI_{n-1}) - 1$. The current list price in year n, CLP_n, is computed from the current list price in year m as follows.

Equation 1

$$CLP_n = CLP_m \times \frac{PPI_n}{PPI_m}$$

Suppose the original list price (when new) for the 1991 combine discussed earlier was known to be \$100,000, i.e., CLP_{1991} = \$100,000. Then the current list price (in 1996) for the same combine is $CLP_{1996} = CLP_{1991} \times PPI_{1996} \div PPI_{1991}$. Using values in Table 1, $CLP_{1996} = \$100{,}000 \times 127.8 \div 116.5 = \$109{,}700$.

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[2] *There are no limitations here. Costs associated with a pre-existing machine can be analyzed as readily as a newly acquired machine. The end of the analysis time period does not have to correspond with an expected machine disposal date. Nonetheless, as will be shown later, certain income tax implications do depend on whether or not a machine is actually bought or sold during the analysis time period.*

[3] *References to particular brands in this paper are for educational purposes only and do not reflect an endorsement by the author.*

[4] *Economists refer to observed prices as nominal prices and observed prices that have been adjusted for inflation as real prices. In this publication prices are nominal prices. When required, adjustments for inflation are made explicit by the formulas.*

Table 1. Producer Price Index, U.S. Average, All Commodities

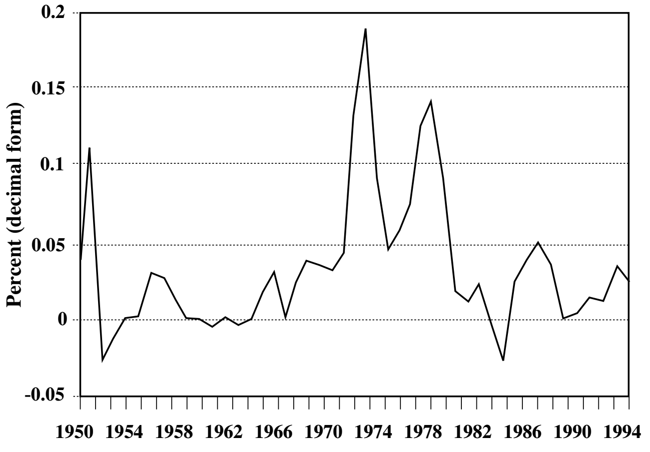
Year	Index	Inflation
1962	31.6500	0.00238
1963	31.5750	-0.00237
1964	31.6333	0.00185
1965	32.2667	0.02002
1966	33.3083	0.03228
1967	33.4000	0.00275
1968	34.2333	0.02495
1969	35.5917	0.03968
1970	36.9000	0.03676
1971	38.1083	0.03275
1972	39.7917	0.04417
1973	45.0250	0.13152
1974	53.4853	0.18786
1975	58.4167	0.09224
1976	61.1333	0.04650
1977	64.8750	0.06121
1978	69.9417	0.07810
1979	78.7250	0.12558
1980	89.8093	0.14079
1981	98.0333	0.09158
1982	100.0167	0.02023
1983	101.2500	0.01233
1984	103.6750	0.02395
1985	103.1500	-0.00506
1986	100.1667	-0.02892
1987	102.8083	0.02637
1988	106.9417	0.04020
1989	112.2417	0.04956
1990	116.2917	0.03608
1991	116.5333	0.00208
1992	117.1917	0.00565
1993	118.9083	0.01465
1994	120.4500	0.01297
1995	124.7583	0.03577
1996	127.8205	0.02455
1997	130.9579	0.02455
1998	134.1723	0.02455
1999	137.4656	0.02455
2000	140.8397	0.02455
2001	144.2966	0.02455
2002	147.8384	0.02455
2003	151.4671	0.02455
2004	155.1849	0.02455
2005	158.9939	0.02455
2006	162.8964	0.02455
2007	166.8947	0.02455

Source: Federal Reserve Bank of St. Louis FRED database (http://www.stls.frb.org/fred)
Notes:
1982=100, 1996 based on monthly indices through August, 1996.
Years 1997-2007 assume same annual inflation rate estimated for 1996.

Because decisions based on machinery cost analysis are always forward-looking, expectations for future inflation rates are required. As an indication of inflation level possibilities, Figure 1 depicts PPI-based inflation from 1950 through 1996 (1996 value based on first 8 months). Most years, inflation levels were in the 0 percent to 5 percent range, with a few years displaying negative inflation (deflation). Two inflation spikes during the 1970s stand out, along with the precipitous decline in the early 1980s. Historically, the preceding year's inflation has been a more reliable indicator of the current year's inflation than has been a longer-term multi-year average. So, PPI values in Table 1 for future years assume the same inflation rate computed for 1996 (i = 0.02455, or around 2.5 percent). Thus, Equation 1 is also used to estimate current list price in future years. For example, $CLP_{2006} = CLP_{1996} \times PPI_{2006} \div PPI_{1996}$ = \$109,700 × 162.9 ÷ 127.8 = \$139,829. Because annual inflation rates are assumed to be the same over the 10 years following 1996, the current list price in 1997 also may be determined with the formula $CLP_{2006} = CLP_{1996} \times (1+ i)^{10}$ = \$109,700 × $(1.02455)^{10}$ = \$109,700 × 1.2745 = \$139,810, which is the same as \$139,829 except for rounding errors.

Figure 1.

Annual Inflation Based on Producer Price Index, 1950–1996



Remaining Value Percentage, Economic Depreciation, and Market Value

Remaining value percentage (RVP) is the percent (in decimal form) that a machine's market value is of its current list price (both evaluated in the same year). RVP helps determine a machine's economic depreciation, which is the amount of market value lost each year due to age, wear, and obsolescence (not to be confused with tax depreciation). For a particular class of machinery, remaining value percentage is often assumed to be determined by its age and not its rate of use, using a constant rate of market value depreciation. Bowers uses the following formula developed by the American Society of Agricultural Engineers (ASAE):

Equation 2

$$RVP_n = RVP1_n = dep1 \times dep2^{AGE_n},$$

$$\text{if } AGE_n \geq 1, \text{ and } 0.85 \text{ if } AGE_n < 1;$$

where RVP_n is RVP in year n (the 1 following RVP distinguishes the ASAE formula from an alternative presented later), AGE_n is a machine's age in years in year n. Depreciation factors for different machinery classes, dep1 and dep2, are in Table 2. Equation 2 states that with 0 inflation a machine depreciates annually at the rate of (1-dep2). That is, each year it is worth dep2 as much as it was the year before.

Figure 2 graphically shows RVP1 values computed from Equation 2 for several classes of machinery. Planters and tillage equipment depreciate more slowly than other classes, and at the end of 20 years, are still worth 29 percent of their current list prices. On the other hand, balers are worth only 12 percent of their current list prices at the end of 20 years. Combines and tractors are in between.

Factors dep1 and dep2 in Equation 2 were computed with and are designed to be used with machinery that is at least 1 year old. Thus, a conditional statement follows the formula in Equation 2. Without that conditional statement, because $dep2^0 = 1$, new machines would be estimated to cost dep1 of current list price. The dep1 values in Table 2 are too low to appropriately value new machines. Instead, new machines are assumed to cost 85 percent of their list prices.

Market value in year n, MV_n, is the remaining value percentage times current list price:

Equation 3

$$MV_n = CLP_n \times RVP_n$$

Economic depreciation is the change in market value across any 2 years, or $MV_n - MV_{n-1}$. Because current list price is affected by inflation, and because remaining value percentage is a measure of economic depreciation, Equation 3 shows that both inflation and economic depreciation affect current market value of machinery. If inflation is high enough to offset economic depreciation, causing CLP to rise rapidly over years, a used machine may sell for more than when it was new.

Continuing with the combine example, the 1996 remaining value percentage is $RVP1_{1996} = dep1 \times dep2^{(1996-1991)}$, or $0.65 \times 0.93^5 = 0.4522$. Inserting the \$109,700 value for CLP_{1996} computed earlier, market value in 1996 is $MV_{1996} = \$109{,}700 \times 0.4522 = \$49{,}606$.

Equation 2 depicts economic depreciation as a fixed cost relating to age. However, because wear is a function of rate of use, if rate of use varies across machines and years, depreciation may have both variable and fixed cost components. For some

Table 2. Factors for Calculating Remaining Value Percentages by Machinery Class.

	Machinery Class					
Factor	Tractors	Combines	Windrowers Mowers	Forage Harvesters	Balers	Planters/ Tillage
dep1	0.67	0.65	0.67	0.56	0.66	0.66
dep2	0.94	0.93	0.90	0.90	0.92	0.96

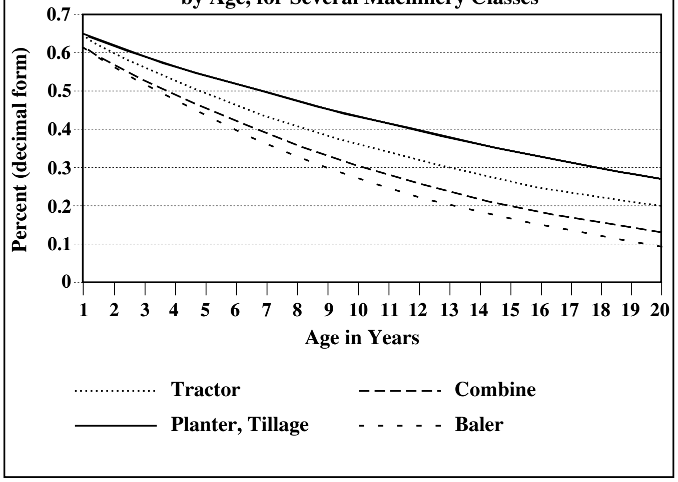
Source: Machinery Replacement Strategies, by Wendell Bowers, Deere and Company, 1994, p.9

Notes:

Factors used to calculate remaining value from age: $RVP = dep1 \times dep2^{AGE}$.

When age is 0 RVP is assumed to be 0.85.

Figure 2. Remaining Value as a Percent of Current List Price by Age, for Several Machinery Classes



machines, most notably for combines, rate of use may be as important for determining market value as is age (Cross and Perry; Kastens, Featherstone, and Biere). This is likely due to the number of used combines that have been originally owned by custom harvesters. Such machines are typically used more intensely and traded more often than farmer-owned machines.

Recently, economists have begun to derive formulas that attempt to quantify the relationship between rate of use and market value, especially for tractors and combines, where hour meters have been standard for many years. However, for tillage and planting equipment, historical rate of use is difficult to quantify. For other classes, such as balers, it may come about because of bale counters. Cross and Perry examined auction sale prices reported monthly from January 1984 to June 1993 in the Farm Equipment Guide (Hot Line, Inc.). Equipment manufactured between 1971 and 1993 were considered. Their study resulted in the following formula relating market value to age and rate of use:

Equation 4

$$RVP_n = RVP2_n = (a+b \times (AGE_n)^c + d \times (HPY_n)^e)^f,$$

if $AGE_n \geq 1$, and 0.85 if $AGE_n < 1$.

Equation 4 depicts an alternative method to Equation 2 for computing remaining value percentage that considers rate of use as well as age. Like $RVP1_n$ in Equation 2, $RVP2_n$ is the proportion (ranging between 0 and 1) that the projected market value in year n is of the current list price in year n. AGE_n is machine age in years at year n. HPY_n is the average hours per year that the machine was used since it was new, evaluated in year n, or $AH_n \div AGE_n$, where AH_n denotes the accumulated hours on the machine as of year n. The small letters, a, b, c, d, e, and f are factors required of the formula. Factor values for several brands of tractors, combines, disks, planters, swathers, and balers are in Table 3.[5] Like Equation 2, Equation 4 requires the conditional statement to value equipment properly when it is less than 1 year old.

Assume the 1991 John Deere combine had 4,000 hours on its hour meter in 1996 so that $HPY_{1996} = 4000 \div 5 = 800$.[6] Using the appropriate values from Table 3, Equation 4 predicts a remaining value percentage of $RVP2_{1996} = [0.94692 - 0.04551 \times 5^{0.87} - 0.00182 \times 800^{0.72}]^2 = 0.2899$. Using the 1996 current list price computed earlier of $109,700, along with Equations 3 and 4, the 1991 machine with 4,000 hours is expected to have a 1996 market value of $31,802. This is substantially less than the $49,606 value computed from Equation 2, partly because of the machine's high usage rate. On the other hand, if the usage rate were 200 hours per year (more typical of a farmer owned machine) rather than 800, Equation 4 predicts a remaining value percentage of 0.4621, yielding a market value of $50,692, much closer to the value calculated using Equation 2.

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[5] *For tractors, in order to allow for horsepower to affect remaining value, the factor a reported in Table 3 must be modified slightly before using in Equation 4. Specifically, for 80-149 horsepower tractors, the value, 0.00046 × pto horsepower, must be subtracted from the associated a values before they can be used in Equation 4. For 150+ horsepower tractors, the value, 0.00093 × pto horsepower, must be subtracted from the associated a values. For all other machinery classes in Table 3, the a's are used as they appear. Formulas reported by Cross and Perry included several additional measures besides age and usage to determine remaining value. Equation 4 was deduced by holding these other measures constant. Thus, it depicts the remaining value percentage for equipment in good condition (contrasted with excellent, fair, or poor) sold at retirement auctions (contrasted with consignment, bankruptcy, or dealer closeout) in the Middle Great Plains (South Dakota, Nebraska, and Kansas).*

[6] *Machinery purchases are assumed to occur at the end of the year. That is, the 4,000 hours are assumed to have accumulated over harvest years, 1992, 1993, 1994, 1995, and 1996. Recent-model combines measure both engine hours and separator hours. Because research-based formulas are based on engine hours that is what is assumed here.*

Table 3. Cross and Perry Adjustment Factors for Selected Machinery Classes and Manufacturers

	Adjustment Factors					
	a*	b	c	d	e	f
80-149 HP Tractors						
AC	0.969772	-0.02725	0.76	-0.00236	0.6	3.846154
Case	1.000787	-0.03277	0.76	-0.00120	0.6	3.846154
Ford	1.029438	-0.02768	0.76	-0.00275	0.6	3.846154
Deere	1.035260	-0.02301	0.76	-0.00120	0.6	3.846154
IH	0.989220	-0.02765	0.76	-0.00203	0.6	3.846154
MF	0.997552	-0.02909	0.76	-0.00261	0.6	3.846154
White	1.032797	-0.02891	0.76	-0.00371	0.6	3.846154
150+ HP Tractors						
AC	1.305504	-0.22785	0.35	-0.01187	0.39	2.222222
Case	1.462469	-0.30023	0.35	-0.01020	0.39	2.222222
Ford	1.238971	-0.11517	0.35	-0.01500	0.39	2.222222
Deere	1.405956	-0.22231	0.35	-0.00766	0.39	2.222222
IH	1.340365	-0.26484	0.35	-0.00547	0.39	2.222222
MF	1.282532	-0.26106	0.35	-0.00155	0.39	2.222222
White	1.408643	-0.25439	0.35	-0.01413	0.39	2.222222
Combines						
AC	0.843972	-0.03779	0.87	-0.00244	0.72	2.0
Case	0.893689	-0.04679	0.87	-0.00091	0.72	2.0
Ford	1.746431	-0.12208	0.87	-0.00771	0.72	2.0
Deere	0.946917	-0.04551	0.87	-0.00182	0.72	2.0
IH	0.925632	-0.04411	0.87	-0.00243	0.72	2.0
MF	0.753825	-0.03811	0.87	-0.00117	0.72	2.0
White	0.792664	-0.03479	0.87	-0.00373	0.72	2.0
NH	0.905448	-0.06141	0.87	-0.00105	0.72	2.0
Disks						
Deere	0.364825	0.60697	-0.85	0	0	2.040816
IH	0.445666	0.55410	-0.85	0	0	2.040816
MF	0.216219	1.95014	-0.85	0	0	2.040816
Kewanee	0.031970	3.06544	-0.85	0	0	2.040816
Krause	0.215375	1.39979	-0.85	0	0	2.040816
Planters						
Deere	0.867382	-0.01939	0.89	0	0	1.960784
IH	0.924203	-0.04245	0.89	0	0	1.960784
Swathers						
Deere	0.855234	-0.04564	0.50	0	0	5.263158
IH	1.077101	-0.10692	0.50	0	0	5.263158
NH	1.062699	-0.10301	0.50	0	0	5.263158
Hesston	0.959780	-0.06955	0.50	0	0	5.263158
Balers						
Deere	0.814355	-0.05939	0.57	0	0	2.777778
IH	1.152865	-0.08524	0.57	0	0	2.777778
NH	0.774934	-0.06093	0.57	0	0	2.777778
Hesston	0.895971	-0.10806	0.57	0	0	2.777778

Source: Cross, T.L. and G.M. Perry. "Depreciation Patterns for Agricultural Machinery." American Journal of Agricultural Economics. 77(February, 1995):194-204.

*For 80 to 149 horsepower tractors, the value 0.00046 × hp must be subtracted from the a factor shown in the table, where hp is the pto horsepower for the tractor considered. For 150+ horsepower tractors, subtract 0.00093 × hp. For other classes of machinery use the a values as they appear.

Figure 3.

Remaining Value as a Percent of Current List Price for Combines with Annual Usage of 200 Hours

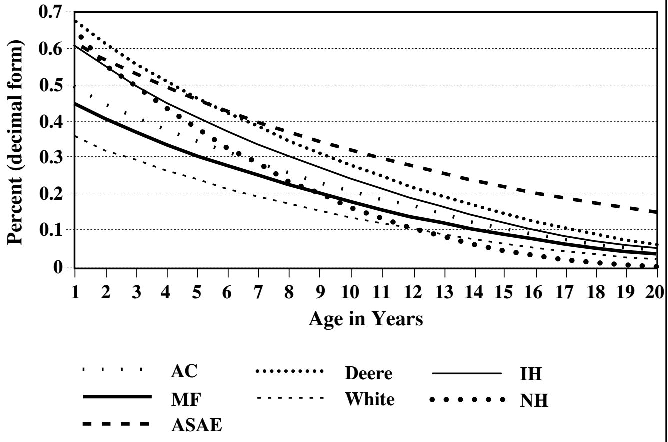


Figure 3 shows computed RVP2 values from Equation 4 for several brands of combines, each with an annual usage of 200 hours. An ASAE line is included so that comparisons can be made with the ASAE estimates for remaining value percentage from Equation 2 (depicted in Figure 2). Deere combines were valued more highly (as a percent of current list price) than other brands after 1 year of usage, followed by New Holland (NH), International Harvester (IH), Allis Chalmers Gleaner (AC), Massey Ferguson (MF), and White. Over the 20 years, except for New Holland, the relative rankings in remaining value are preserved. New Holland combines were valued highly after one year; however, they depreciated more rapidly and at 20 years of age are valued the lowest among the combines. In general, the ASAE formula values combines more highly than do the Cross and Perry formulas.[7]

Figure 4.

Annual Depreciation as a Percent of Previous Year's Price for Combines with Annual Usage of 200 Hours

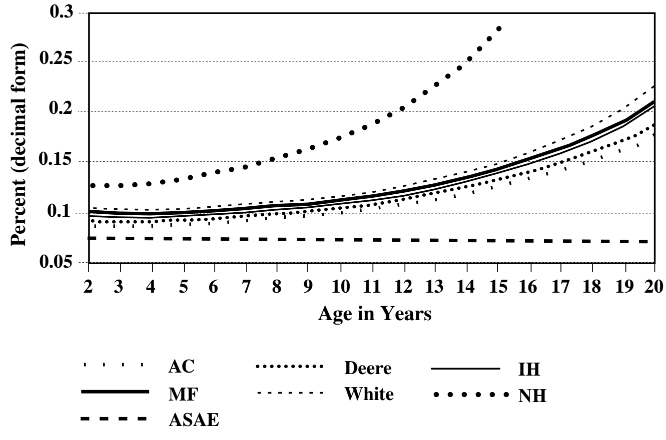
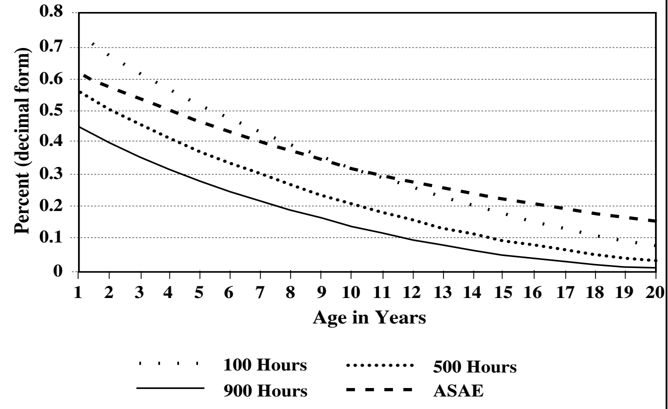


Figure 4 shows the annual depreciation rates associated with the RVP2 values shown in Figure 3. The rapid depreciation associated with New Holland combines is immediately apparent. In addition, the sharp contrast between Cross and Perry values and ASAE values is also apparent. The ASAE formula assumes constant depreciation (7 percent of previous year's value). On the other hand, Cross and Perry results show that the rate of depreciation for combines actually increases over time, and at an increasing rate. This could be due to high timeliness losses associated with breakdowns during harvest. That is, combines lose their reliability quickly.

Figure 5.

Remaining Value as a Percent of Current List Price for a Deere Combine across Various Annual Usage Rates



Remaining value percentages for a Deere combine across different annual usage rates are shown in Figure 5. After 1 year of use, a combine used 900 hours is valued at only 60 percent of a combine used only 100 hours (0.43 ÷ 0.72). This emphasizes the potential value of using remaining value formulas that explicitly account for usage rate. An operator who plans to use a purchased combine intensively, as in custom harvesting, would be especially ill-advised to ignore usage rate as a determinant of future used combine value.

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[7] *In comparing machinery values across different brands, it is important to note that individual models within a single brand may vary substantially in value. That is, a poorly ranked brand may have some models that retain their value better than the average model for a more highly ranked brand.*

Figure 6.

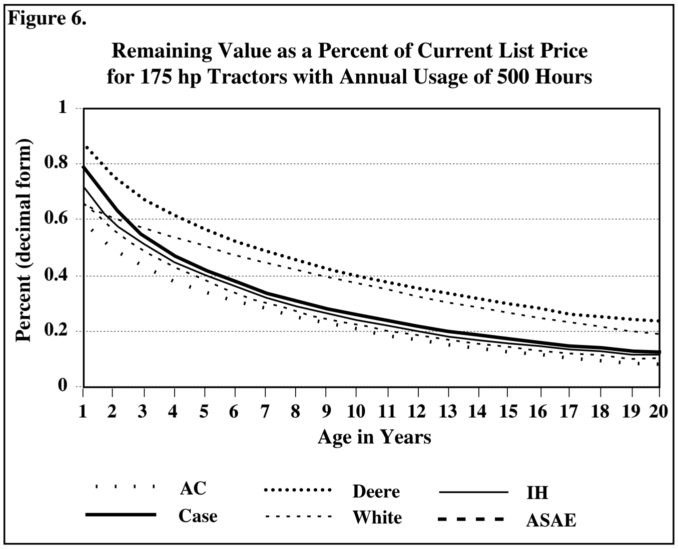
Remaining Value as a Percent of Current List Price for 175 hp Tractors with Annual Usage of 500 Hours

Figure 6 shows computed RVP2 values from Equation 4 for several brands of tractors within the 150+ hp class. The values were computed for tractors with 175 horsepower. Each tractor was assumed to have 500 hours of annual usage. As before, an ASAE line is included so that comparisons can be made with the ASAE estimates for remaining value from Equation 2. Deere tractors were valued more highly after 1 year of age, and the gap between Deere and other brands remained throughout the 20 years. Further, Deere tractors were the only ones that were consistently above the ASAE line. Relative to other brands, AC tractors were substantially devalued after one year of age. However, with the exception of Deere, all tractors were valued similarly after around 7 years (assuming similar list prices).

Figure 7.

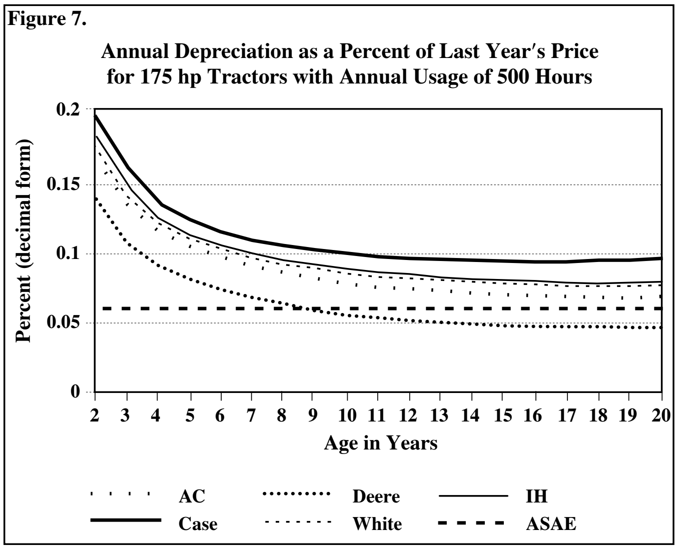
Annual Depreciation as a Percent of Last Year's Price for 175 hp Tractors with Annual Usage of 500 Hours

Figure 7 shows the depreciation associated with the remaining values shown in Figure 6. Unlike combines (Figure 4), where depreciation rises with age, depreciation for tractors falls with age. Likely, this reflects tractors being traded to less-intensive users as they age–users who may be less concerned about the timeliness risks associated with breakdowns. As before, the curved depreciation paths contrast sharply with the straight line for ASAE.

Instead of solving for market value when current list price and remaining value percentage are known, Equation 3 may be used to solve for current list price when market value and remaining value percentage are known:

Equation 5

$$CLP_n = MV_n \times \frac{1}{RVP_n}$$

RVP_n could be determined from either Equation 2 or 4. Equation 5 is useful when used market value is known but list price is not, as when a used machine is purchased at the market. Suppose that the used 1991 combine was purchased in 1996 for $50,000, and that RVP_{1996} was computed from Equation to be 0.4522. Then, Equation 5 predicts a current list price in 1996 of $110,571. Equation 5 presents a third approach for determining current list price–in addition to the two methods discussed previously.

Purchase Price and Selling Price

Machinery cost analysis must account for changes in valuation as well as any associated cash flows. One way to accomplish this is to consider a purchase (PUR) and a selling (SELL) price, each occurring at market value in the year it occurs. Even if a machine is already owned, this method accounts for changes in the machine's value over time. Although a machine is purchased only once in our analysis, it is helpful in spreadsheet formulas to think of PUR as being valued in each year. That is, PUR is valued at market value only in the year it is purchased (here, 1996), and otherwise it equals 0:

Equation 6

$PUR_n = MV_n$; if n = *begin*, else 0.

Similarly, the selling price in year n, $SELL_n$, is

Equation 7

$$SELL_n = MV_n;\ \text{if } n = \textit{end}, \text{ else } 0.$$

Annual Operating Costs

Field Efficiency

Although machine costs per acre are desired, some cost components are determined by hours of operation. The concept of field efficiency is used to help make the transition from hours of use to acres covered. If field efficiency were 100 percent, acres covered per hour would be only a function of operating speed and machine width. However, time spent moving machinery between fields (which may be large for producers with many small fields), overlapping, and backtracking on point rows all diminish field efficiency. Along with other machinery operation guidelines, Table 4 provides typical field efficiency percentage (FEP) values for selected field operations. Thus, acres per hour (APH) is a function of field speed (FS) in miles per hour, machine width (MW) in feet, and FEP in decimal form (Note: 5,280 feet per mile and 43,560 square feet per acre):

Equation 8

$$APH = \frac{FS \times MW \times 5{,}280}{43{,}560} \times FEP$$

$$= 0.1212 \times FS \times MW \times FEP$$

With a travel speed of 3 miles per hour, a field efficiency of 70 percent, and a 30-foot wide cutter platform, 7.6 acres are harvested per hour of combine operation according to Equation 8.

The expected number of total acres (land acres × number of operations) to be covered annually by a machine operation can be used along with APH from Equation 8 to determine the expected annual hours of run time accumulated by the machines involved. Comparing this value with experience provides a good check on the validity of Equation 8. For example, if including all operations involving the use of a tractor results in an expected total annual tractor use of 500 hours, but actual annual hours have been averaging 700 hours, that is an indication FEP is lower than assumed.

Fuel and Lubrication

Table 5 shows average energy and fuel requirements for various field operations. The table shows that harvesting one acre of wheat with a diesel combine requires 1.0 gallon of fuel. When 7.6 acre per hour is multiplied by 1.0 gallon per acre of fuel the result is 7.6 gallons per hour of diesel fuel used in harvesting wheat. Lubrication costs average 10 percent of fuel costs (Bowers). If diesel fuel is projected to cost $0.90 per gallon in 1997, then fuel and lubrication charges in the same year are 7.6 × 0.90 × 1.10 = $7.52 per hour. If the combine owner intends to harvest 760 acres of wheat per year, implying 100 machine hours, then the fuel and lubrication (FL) charge assigned to this operation in 1997 is FL_{1997} = $752. Because 1997 is the first year the machine is used $FL_{1996} = 0$.[8]

Labor

An hourly charge for labor needs to cover total operator costs. For example, it should include the employer's share of Social Security tax, as well as any other fringe benefits. The combine operation time of 100 hours for the wheat combining example accounts for field inefficiencies. However, the actual labor hours used in a field operation are regularly more than the machine hour meter suggests, due to the time spent checking on field conditions and driving to and from fields (as in when machinery is left in the field overnight). If we assume actual labor is 20 percent more than machine hours, annual labor charges (LAB) assigned to the 100 hours of combine operation is: LAB = hourly labor charge × machine hours × 1.20. If the per hour cost of labor (cost to employer) is expected to be $10 in 1997 then the wheat combining operation would be assigned a 1997 labor charge of LAB_{1997} = $1,200. Again, $LAB_{1996} = 0$.

To allow for change in general price levels over time, expected fuel and lubrication charges as well as labor charges should account for inflation. That is, for some year n, $FL_n = FL_{1997} \times PPI_n \div PPI_{1997}$.

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[8] *In a spreadsheet setting, with columns corresponding to alternative costs (or intermediate steps to get there) and rows corresponding to years, it is important to note that some columns have entries in the row corresponding to year = 0 but others do not. In this case, the FL value in the 1996 row (n = begin, or k = 0) must either be left blank or set equal to 0. Alternatively, if a formula is desired that is consistent across all spreadsheet rows (including the row where n = begin, or k = 0), a conditional statement that sets* FL_n *to 0 when n = begin must be included.*

Table 4. Field Efficiency, Field Speed, and Repair and Maintenance Factors for Field Operations

	Field Efficiency		Field Speed		EUL		Repair Factors	
	Range %	Typical %	Range mph	Typical mph	Est. Life hours	Tot. Life Cost%[a]	RF1	RF2
TRACTORS								
2WD & stationary					12,000	100	0.007	2.0
4WD & crawler					16,000	80	0.003	2.0
TILLAGE & PLANT								
Moldboard plow	70-90	85	3.0-6.0	4.5	2,000	100	0.29	1.8
Heavy-duty disk	70-90	85	3.0-6.0	4.5	2,000	60	0.18	1.7
Tandem disk harrow	70-90	80	4.0-7.0	6.0	2,000	60	0.18	1.7
(Coulter) chisel plow	70-90	85	4.0-6.5	5.0	2,000	75	0.28	1.4
Field Cultivator	70-90	85	5.0-8.0	7.0	2,000	70	0.27	1.4
Spring tooth harrow	70-90	85	5.0-8.0	7.0	2,000	70	0.27	1.4
Roller-packer	70-90	85	4.5-7.5	6.0	2,000	40	0.16	1.3
Mulcher-packer	70-90	80	4.0-7.0	5.0	2,000	40	0.16	1.3
Rotary hoe	70-85	80	8.0-14.0	12.0	2,000	60	0.23	1.4
Row crop cultivator	70-90	80	3.0-7.0	5.0	2,000	80	0.17	2.2
Rotary tiller	70-90	85	1.0-4.5	3.0	1,500	80	0.36	2.0
Row crop planter	50-75	65	4.0-7.0	5.5	1,500	75	0.32	2.1
Grain drill	55-80	70	4.0-7.0	5.0	1,500	75	0.32	2.1
HARVESTING								
Corn picker sheller	60-75	65	2.0-4.0	2.5	2,000	70	0.14	2.3
PT Combine	60-75	65	2.0-5.0	3.0	2,000	60	0.12	2.3
SP Combine	65-80	70	2.0-5.0	3.0	3,000	40	0.04	2.1
Mower	75-85	80	3.0-6.0	5.0	2,000	150	0.46	1.7
Mower (rotary)	75-90	80	5.0-12.0	7.0	2,000	175	0.44	2.0
Mower-conditioner	75-85	80	3.0-6.0	5.0	2,500	80	0.18	1.6
Mow-cond (rotary)	75-90	80	5.0-12.0	7.0	2,500	100	0.16	2.0
SP Windrower	70-85	80	3.0-8.0	5.0	3,000	55	0.06	2.0
Side delivery rake	70-90	80	4.0-8.0	6.0	2,500	60	0.17	1.4
Square baler	60-85	75	2.5-6.0	4.0	2,000	80	0.23	1.8
Large square baler	70-90	80	4.0-8.0	5.0	3,000	75	0.10	1.8
Large round baler	55-75	65	3.0-8.0	5.0	1,500	90	0.43	1.8
Forage harvester	60-85	70	1.5-5.0	3.0	2,500	65	0.15	1.6
SP Forage harvester	60-85	70	1.5-6.0	3.5	4,000	50	0.03	2.0
Sugar beet harvester	50-70	60	4.0-6.0	5.0	1,500	100	0.59	1.3
Potato harvester	55-70	60	1.5-4.0	2.5	2,500	70	0.19	1.4
SP Cotton picker	60-75	70	2.0-4.0	3.0	3,000	80	0.11	1.8
MISCELLANEOUS								
Fertilizer spreader	60-80	70	5.0-10.0	7.0	1,200	80	0.63	1.3
Boom-type sprayer	50-80	65	3.0-7.0	6.5	1,500	70	0.41	1.3
Bean puller/windrower	70-90	80	4.0-7.0	5.0	2,000	60	0.20	1.6
Beet topper/chopper	70-90	80	4.0-7.0	5.0	1,200	35	0.28	1.4

Source: ASAE Standards 1993, American Society of Agricultural Engineers, St. Joseph, Michigan, 1993, p.332.

[a] percent of current list price

Similarly, $LAB_n = LAB_{1997} \times PPI_n \div PPI_{1997}$. For example, in 2003, fuel and lubrication charges are expected to be $FL_{2003} = \$752 \times 151.5 \div 131.0 = \$870$, where PPI values are taken from Table 1.

Repair and Maintenance

The ASAE describes accumulated charges for repair and maintenance (ARM) for a particular machine as a function of the machine's current list price, accumulated use of the machine in hours (AH), and two factors specific to the machine, RF1 and RF2. However, if a machine's hours are beyond its estimated useful life (EUL)–a convenient mathematical threshold, not necessarily indicative of limits to use–then the machine is assumed to accumulate repairs at the same hourly rate it did when at its estimated useful life. Values for RF1, RF2, and EUL are found in Table 4. The formula that calculates a machine's accumulated repair and maintenance costs is

Equation 9

$$ARM_n = RF1 \times CLP_n \times \left(\frac{AH_n}{1{,}000}\right)^{RF2}, \text{ if } AH_n \leq EUL$$

else,

$$RF1 \times CLP_n \times \left(\frac{EUL}{1{,}000}\right)^{RF2} \times$$

$$\left[1 + RF2 \times \left(\frac{AH_n - EUL}{EUL}\right)\right], \text{ if } AH_n > EUL$$

Suppose that the hour meter on the 1991 John Deere combine displayed 1,000 hours when it was purchased in 1996 . Assuming that the future usage rate will be 200 hours per year, then $AH_{1997} = 1{,}200$ and $AH_{2003} = 2{,}400$. The repair and maintenance charge for a particular year n, RM_n, is defined as:[9]

Equation 10

$$RM_n = ARM_n - ARM_{n-1}; \text{ if } n > \textit{begin}, \text{ else } 0$$

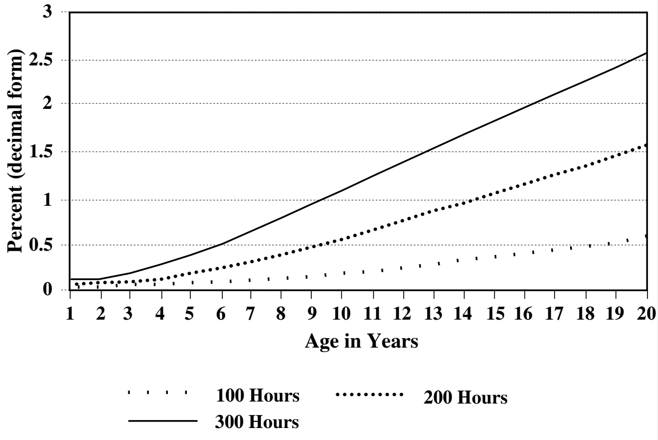
We know that $CLP_{1996} = \$109{,}700$, and from Equation 1, $CLP_{1997} = CLP_{1996} \times PPI_{1997} \div PPI_{1996} = \$109{,}700 \times 131.0 \div 127.8 = \$112{,}447$. Table 4 shows that, for a self-propelled combine, RF1 and RF2 are 0.04 and 2.1, respectively. Then, using Equation 9 and Equation 10, the repair charge for 1997 is:

$$RM_{1997} = [0.04 \times \$112{,}447 \times (1200 \div 1000)^{2.1}] - [0.04 \times \$109{,}700 \times (1000 \div 1000)^{2.1}] = \$6{,}596 - \$4{,}388 = \$2{,}208.$$

Figure 8 shows accumulated repair and maintenance costs (as a percent of current list price) for a tandem disk over 20 years based on 3 usage rates. Because Table 4 shows estimated useful life for the disk to be 2,000 hours, at 100 hours per year the useful life is not reached until after year 20. The slight upward curvature in the 100-hour line shows that each additional hour of usage adds more repairs than the previous hour of usage. Equation 9 states that once the useful life is reached repairs accumulate at the same rate per hour of usage. Consequently, the 200-hour line becomes linear at 10 years because 2,000 ÷ 200 = 10. Similarly, the 300-hour line becomes linear at around 7 years. Table 4 states that a tandem disk will have accumulated repair and maintenance costs over its useful life equal to 60 percent of the disk's current list price. Thus, in Figure 8, a horizontal line drawn at 60 percent would cross the 100-, 200-, and 300-hour lines at 20, 10, and 7 years, respectively. By the time a disk used at 300 hours per year is 20 years old, repairs will have accumulated equal to around 2.5 times that disk's current list price. Varying usage rates for other classes of machinery will result in accumulated repair graphs similar in shape to Figure 8. For example, Table 4 shows that accumulated

Figure 8.

Accumulated Repairs as a Percent of Current List Price for a Tandem Disk across Three Annual Usage Rates



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[9] *The machine is not used in the year of purchase. In this case, although there exists an ARM_{1996} value, the first annual repair bills (also fuel and labor) occur in 1997. So, $RM_{1996} = 0$.*

Table 5. Average Energy and Fuel Requirements for Selected Machinery Operations

		Gasoline	Diesel	LP Gas
Avg fuel consump. per max pto hp (gal per hr)>		0.068	0.044	0.08
Field Operation	PTO hp-hrs/acre	Gasoline gal/acre	Diesel gal/acre	LP Gas gal/acre
Shred stalks	10.5	1.00	0.72	1.20
Plow 8-in deep	24.4	2.35	1.68	2.82
Heavy offset disk	13.8	1.33	0.95	1.60
Chisel Plow	16.0	1.54	1.10	1.85
Tandem disk, stalks	6.0	0.63	0.45	0.76
Tandem disk, chiseled	7.2	0.77	0.55	0.92
Tandem disk, plowed	9.4	0.91	0.65	1.09
Field cultivate	8.0	0.84	0.60	1.01
Spring-tooth harrow	5.2	0.56	0.40	0.67
Spike-tooth harrow	3.4	0.42	0.30	0.50
Rod weeder	4.0	0.42	0.30	0.50
Sweep plow	8.7	0.84	0.60	1.01
Cultivate row crops	6.0	0.63	0.45	0.76
Rolling Cultivator	3.9	0.49	0.35	0.59
Rotary hoe	2.8	0.35	0.25	0.42
Anhydrous applicator	9.4	0.91	0.65	1.09
Planting row crops	6.7	0.70	0.50	0.84
No-till planter	3.9	0.49	0.35	0.59
Till plant (with sweep)	4.5	0.56	0.40	0.67
Grain drill	4.7	0.49	0.35	0.59
Combine (small grains)	11.0	1.40	1.00	1.68
Combine, beans	12.0	1.54	1.10	1.85
Combine, corn & milo	17.6	2.24	1.60	2.69
Corn picker	12.6	1.61	1.15	1.93
Mower (cutterbar)	3.5	0.49	0.35	0.59
Mower conditioner	7.2	0.84	0.60	1.01
Swather	6.6	0.77	0.55	0.92
Rake, single	2.5	0.35	0.25	0.42
Rake, tandem	1.5	0.21	0.15	0.25
Baler	5.0	0.63	0.45	0.76
Stack wagon	6.0	0.70	0.50	0.84
Sprayer	1.0	0.14	0.10	0.17
Rotary Mower	9.6	1.12	0.80	1.34
Haul small grains	6.0	0.84	0.60	1.01
Grain drying	84.0	8.40	6.00	10.08
Forage harvester, green	12.4	1.33	0.95	1.60
Forage harv, haylage	16.3	1.75	1.25	2.10
Forage harvester, corn	46.7	5.04	3.60	6.05
Forage blower, haylage	3.3	0.35	0.25	0.42
Forage blower, corn silage	18.2	1.96	1.40	2.35

Source: Machinery Replacement Strategies, by Wendell Bowers, Deere and Company, 1994, p.80,81.

self-propelled combine repairs will reach 40 percent of current list price when the combine has accumulated 3,000 hours.

In practice, repair and maintenance costs vary substantially across operators due to differences in management styles. One producer may spend little time on maintenance, hoping that gains in timeliness offset potential additional repairs. Others may be especially careful with maintenance, believing that the extra labor costs will be offset by reduced repair costs. Thus, a personal repair adjustment factor (RAF), may be multiplied by the RM_n in Equation 10 to better represent true repair cost. Bowers suggests that actual repair and maintenance costs may vary as much as ± 25 percent from those computed by Equation 10. Consequently, RAF is valued at something between 0.75 and 1.25, and Equation 10 is modified to:

Equation 11

$$RM_n = (ARM_n - ARM_{n-1}) \times RAF; \text{ if } n > \textit{begin}, \text{ else } 0$$

The repair and maintenance value established in Equation 11 does not require adjustment for inflation because the embedded CLP value already accounts for it. It should be noted that the RAF should not be made excessively low just because projected current repairs in a spreadsheet setting appear high ten years from now. This is because inflation is easy to understand after it has been experienced, but often is more difficult to believe into the future. Even a relatively modest inflation rate of 3 percent (low by historical standards as the average PPI-based inflation from 1963 through 1995 was 4.3 percent) translates a current (1996) repair bill of $1,000 into $1,344 10 years from now–without any consideration for the additional repairs required of an aging machine.

Repair and maintenance values derived from Equation 11 may also appear "too high" if they are compared to traditional repair and maintenance categories in farm accounting systems. Such accounts may not include the labor portion of repairs and maintenance provided on farm. Also, they may not account for items such as depreciation on farm shop tools and farm shop buildings. Consequently, absent a detailed understanding of historical on-farm repair costs, it is appropriate to use the values from Equation 11 with RAF set to 1.0.

Equations 9 through 11 do not account for repairs covered by warranties. Thus, for age or usage rates within warranty periods a further adjustment of Equation 11 is required to subtract out any warranty coverage of repairs and maintenance. Because the adjustment is highly machine-specific it is not included.

Timeliness

Timeliness costs are associated with a reduction in quantity or quality of crops harvested resulting from operations not being performed at optimal times. For some operations, such as planting or harvesting, timeliness costs may rise rapidly after optimal time periods are exceeded. Because timeliness costs are highly location-, crop-, and year-specific (timeliness costs may be especially high in wet years) they are not generalized in formulas here. However, careful comparisons between experience and calculated annual machine hours should provide clues to potential timeliness problems. For example, if it is known that a wheat harvest lasting longer than 10 days normally results in excessive yield losses, and a wheat combine cost analysis projects annual machine hours of 200, then purchasing a larger combine should be considered. More specifically, comparing the per acre costs for a small combine requiring 12 days to complete harvest with those of a larger combine (with higher per acre costs), requiring only 10 days, results in a break-even crop loss that could be tolerated with the lower capacity machine. The break-even crop loss can be compared with the expected loss associated with harvesting 2 days longer than the optimal harvest period to help select the most profitable combine.

Using Equation 4 for remaining value calculations, which explicitly accounts for usage rate, may lessen some of the problems associated with inadequately accounting for timeliness costs. Specifically, although per acre depreciation costs rise with less intensive use (since depreciation is spread over fewer acres), Equation 2 depicts a greater rise in per acre depreciation costs with less intensive use than does Equation 4. In short, Equation 4 assigns less penalty for operating machinery that appears oversized due to omitting timeliness costs, which means an operator may choose slightly larger machinery by using Equation 4, which helps cover risks associated with timeliness.

Property Taxes, Insurance, and Shelter

Taxes (property taxes, not income taxes) insurance, and shelter (TIS) are typically considered a fixed machinery cost (usually a set percentage of market value). However, if market value depends on usage rate, as in Equation 4, then even TIS has variable cost components. Presently (1996) Kansas has no property tax on farm machinery, so only insurance and shelter must be considered. We assume TIS is 1.5 percent of market value. Because market value already accounts for inflation, no additional adjustment is required. The TIS_n formula (with n beginning in 1997, so $TIS_{1996} = 0$) is

Equation 12

$$TIS_n = MV_n \times 0.015$$

Income Tax and Finance

Marginal Tax Rates

In general, a marginal tax rate is the amount of income-related taxes that must be paid on the last dollar of taxable profit. Because machinery decisions affect several years in the future, an expected marginal rate should be used, rather than the specific rate applied to a single year. Furthermore, because some machinery costs offset self-employment income and others offset only capital gains or depreciation recapture, it is useful to consider two marginal tax rates. The first rate, T1, includes both federal and state income tax rates. The second rate, T2, includes the self-employment tax as well.

Suppose a sole proprietor oscillates between a marginal federal rate of 0.15 one half of the time and 0.28 the other half of the time. Then, the expected marginal federal rate is 0.215. Combining 0.215 with a Kansas income tax rate of around 0.0485 implies T1 = 0.2635. Self-employment taxes are presently 0.1513. However, because one half of self employment taxes are income tax deductible, the net self-employment tax rate is $SE = 0.1513 - {}^1/_2\,(0.1513) \times T1 = 0.1365$. Because T2 is the sum of federal and state income tax rates, plus the self-employment tax rate, T2 = T1 + SE = 0.2635 + 0.1365 = 0.40. This rate effectively makes after-tax cost for expenses such as fuel and repairs only 60 percent of the cash outlays associated with those expenses. Because farm corporations do not pay self employment taxes, for them T2 = T1.[10]

Cost of Capital

Machinery is purchased with debt funds, equity funds, or some combination of the two. When debt funds are used there is an explicit interest charge. The cost of debt funds is the rate at which machinery investment funds may be borrowed. When equity funds are used there is an implicit charge referred to as opportunity cost. That is, equity funds could have been used elsewhere in the operation (as in expansion), or in outside investment (such as in the stock market). The opportunity cost of equity funds is often considered to be the average or expected rate of return on equity. Because interest is tax deductible, and because producers are ultimately interested in after-tax income, the cost of capital rate is often reduced by the marginal tax rate, making it an after-tax cost of capital rate.

One way to reduce the cost of capital (COC) to a single value is to weight the cost of debt by the long run portion of debt used in the operation, and the cost of equity by the long run portion of equity in the operation. Let K_e be the typical annual rate of return on equity for the farm, that is, the average annual net farm income (before paying income taxes, but after accounting for any charges for unpaid labor, and after accounting for economic depreciation or appreciation of capital items), divided by the net worth at the beginning of the year. Let K_d be the annual interest rate charged by a lender on machinery loans. Let W_d be the percentage of debt funds typically used in the operation (average debt to assets ratio). Then, cost of capital can be described by

Equation 13

$$COC = [K_e \times (1 - W_d) + K_d \times W_d] \times (1 - T2)$$

The 1- T2 term at the right of Equation 13 shows that the calculated COC is an after-tax rate. If a farm has a typical debt to assets ratio of 0.6 and a typical return on equity of 0.12, and the lender's interest rate is 0.10, then using the tax rate of T2 = 0.40 implies that COC = [0.12 × (1 - 0.60) + 0.10 × 0.40] × (1 - 0.40) = 0.0648.

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[10] *This is most relevant for corporations that tend to use profits to build farm equity rather than pay out profits to their shareholders in the form of wages or dividends.*

In general, it should be the case that $K_e \geq K_d$ because it is highly unlikely that the long-run return on farm equity would be lower than the long-run interest rate on loans. If it were, equity funds would be used to pay down debt. Likewise, it is also unlikely that the long-run return on equity would be substantially higher than the long-run interest rate on loans. If it were, producers would demand more loans, causing the interest rate to rise. In short, market forces tend to keep the interest rate on loans near the rate of return on farm equity. Equation 13 can be simplified by defining the cost of capital as only the after-tax interest rate on machinery loans, or $COC = K_d \times (1 - T2)$.

Closely related to cost of capital is real cost of capital (or, real interest rate). Where i denotes inflation, the real cost of capital is defined as $[(1 + COC) \div (1+i)] - 1$, and represents the cost of capital after allowing for inflation. If inflation is greater than COC, the real cost of capital is negative, and the incentive to invest in inflation-tracking capital items is large. Such was the case in the last half of the 1970s, when producers borrowed heavily to invest in machinery and land where expected inflationary returns were larger than the cost of borrowed funds.

Net Present Value

As noted at the outset, an ultimate goal of machinery cost/investment analysis is to reduce the combined net cash flows associated with one machinery scenario over time to a single annual value. The task begins by reducing the net cash flows for each machine in the scenario to a single annual value. The concept of net present value (NPV), or discounted cash flow, is used to perform the valuations. The basic idea is that a dollar in hand today is worth more than a dollar to be received sometime in the future because today's dollar can be invested to generate earnings. Therefore, future dollars are discounted relative to today's dollars, and dollars to be received further in the future are discounted more than dollars received in the near future. For the examples used here, because COC represents the opportunity cost of funds, it also is the relevant discount rate in the NPV analysis.

With the Greek letter Σ representing the sum, with K representing the total number of years in the projection, with CF_k representing the net cash inflow in the kth year (outflows are negative inflows), and with COC representing the discount rate in decimal form, the formula for net present value is

Equation 14

$$NPV = \sum_{k=0}^{k=K} \frac{CF_k}{(1+COC)^k}$$

NPV is computed in year 0 (k = 0).[11] Suppose a farm operator purchases a machine in 1996 to be used over the next 4 years (K = 4), or 1997 to 2000. Assuming no usage in 1996, the net cash flow in year 0 (1996) may be positive due to an income tax savings. Say it is \$100. Assume that, due to operating costs, the net cash inflow in each year, 1997 to 1999, is –\$200. Suppose further that in 2000 the machine is sold for an amount greater than the sum of the final year's operating expenses. Say the net inflow that year is \$30. Finally, assume that the operator's discount rate (the after-tax loan rate) is 6 percent, or COC = 0.06. Equation 14 then yields

Equation 15

$$NPV = \frac{100}{(1 + 0.06)^0} + \frac{-200}{(1 + 0.06)^1} + \frac{-200}{(1 + 0.06)^2} + \frac{-200}{(1 + 0.06)^3} + \frac{30}{(1 + 0.06)^4} = -410.84$$

The net present value of the machine's cash flow stream over the 5 years considered (1996 to 2000) is –\$410.84. The interpretation is that the operator is indifferent between the cash flow stream presented and merely paying out \$410.84 in 1996.

To show why the operator would be indifferent between the 5-year cash flows presented and paying out \$410.84 in 1996 suppose that \$410.84 is invested in year 0 at the annually compounded rate of 0.06. In year 0 the investment would be worth \$510.84 because of the \$100 net cash inflow that year. In year 1 it would be worth (\$510.84 – \$200) + (0.06 × \$510.84) = \$341.49, and so on. After year

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[11] *Earlier we used the subscript n to denote years such as 1996, 1997, etc. This was especially important for the PPI indexes which are year-specific. Now we are using only the subscript k, where the year of machine purchase (in our examples, 1996) is mapped to k = 0, the following year to k = 1, and so on. This is helpful because the subscript itself is used mathematically in the net present value formulas.*

4 the investment is worth \$0. That is, the \$410.84 investment would have been exactly the amount needed to meet the annual cash flows required.

As long as the time horizons are the same for both, two machines or machine operations can be directly compared using their respective NPVs. The machine with the largest NPV (least negative if both values are negative) is preferred. Furthermore, the NPVs for all machines in a machinery scenario associated with one cropping system can be summed to provide an NPV for the machinery scenario–to be compared with the NPV for the machinery scenario of an alternative cropping system.

Amortized Annual Cash Flow

As presented in the preceding section, NPV is a measure of total costs over the years in the planning horizon. Thus, when time horizons differ across investments, comparing NPVs is not appropriate. Furthermore, even if horizons are comparable, producers may be more accustomed to thinking of annual costs. For example, it is difficult to compare NPV of a machinery operation with custom rates. What is needed is an annual number that begins in year 1, and stays the same over the projection years, except for rising or falling with inflation (as custom rates might do). NPV is reduced to this annual series through the amortization process. The formula for the inflation-adjusted amortized annual cash flow ($IAACF_k$) associated with an NPV computed over K years is

Equation 16

$$IAACF_k = \frac{\left(\frac{1 + COC - 1}{1 + i}\right)}{1 - \left(\frac{1 + COC}{1 + i}\right)^{-K}} \times NPV \times (1 + i)^k ;$$

for k = 1 … K

where i is the expected inflation rate over the next 4 years (1997 to 2000).

In Equation 16, values for k begin at 1 rather than 0 because the machine whose costs are amortized is assumed to be first used in year 1 (in this case, 1997). That is, a comparison with custom rates would begin in year 1 because that is the first year custom charges would apply. Because k only appears as the last element in Equation 16 it is clear that an IAACF value for one year is (1+i) times as large as the IAACF value of the year before (i.e. last year's value, only adjusted for inflation). That is, $IAACF_k = IAACF_{k-1} \times (1+i)$. For this reason, even though supposed cash flow is 0 in year 0, it is helpful to begin by computing $IAACF_0$. Furthermore, if a producer wishes to compare with custom rates in year 0 (custom rates for 1996 may be more familiar than projected 1997 custom rates), then $IAACF_0$ provides the appropriate comparison value.

If an inflation rate of i = 0.02 is used (from the annual rate projected in Table 1 for the years 1997 to 2000), along with COC = 0.06, then $IAACF_0 = \{[(1.06 \div 1.02) - 1] \div [1 - (1.06 \div 1.02)^{-4}]\} \times (-\$410.84) \times 1.02^0 = -\$112.97$ for the machine example described. The IAACF value for 1997 is $IAACF_1 = IAACF_0 \times (1+i)^1 = -\$112.97 \times 1.02 = -\$115.23$. Similarly, $IAACF_2 = IAACF_1 \times 1.02 = -\$117.54$, $IAACF_3 = IAACF_2 \times 1.02 = -\$119.89$, and $IAACF_4 = -\$122.29$.

The amortization results described provide another comparative cash flow stream. Essentially, the operator is indifferent between the three streams of annual cash flows: a) the actual cash flows as they occur: {100, –200, –200, –200, 30}; b) the results of Equation 14 depicted in Equation 15: {–410.84, 0, 0, 0, 0}; and c) the results of Equation 16: {0, –115.23, –117.54, –119.89, –122.29}; with the first number in each series pertaining to 1996 and the last to 2000. The advantage to using the method depicted by Equation 16, or stream (c), is that it allows for a straightforward comparison between a machine's cost and an alternative such as custom rates, which are modified by inflation over the time period examined. If the machine's tasks could be hired in year 1 for less than \$115.23 then it is more profitable to do so and not purchase the machine, or if they could be hired for less than \$112.97 in year 0.

Finance

As long as the after-tax interest rate charged on a loan is equal to the discount rate (here, the cost of capital), exactly how a loan is structured is immaterial. That is, net present value is unaffected. Consider two extreme financing possibilities for a \$1,000 machine purchased in year 0 and sold in year 3 for \$500, with an after tax interest rate and discount rate of 0.10. In the first case, the full \$1,000 principal is paid off in year 0, so yearly interest charges are 0. That would be analogous to purchasing the machine with cash and not even taking out a loan. The cash flow stream is {-1000, 0, 0, 500}. NPV = [-1000 ÷ $(1.10)^0$] + [0 ÷ $(1.10)^1$] + [0 ÷ $(1.10)^2$] + [500 ÷ $(1.10)^3$] = -$624.34. In the second case, the full amount is borrowed with a balloon principal payment at the end equal to $1,000. Year 0 has no net cash outlay (the loan amount offsets the purchase amount) and years 1 and 2 have only interest payments of 10 percent, or $100, each year. Year 3 has a $100 interest payment, a $1,000 principal payment, and a $500 cash receipt, for a net cash flow of -$600. NPV = [0 ÷ $(1.10)^0$] + [–100 ÷ $(1.10)^1$] + [–100 ÷ $(1.10)^2$] + [–600 ÷ $(1.10)^3$] = -$624.34.

As the preceding example shows, machinery costs can often be analyzed without considering the finance decision. This is due to two factors in the example, (a) the discount rate equals the cost of capital, and (b) the cost of capital equals the after-tax interest rate on farm loans. Although violations of (a) are unlikely, violations of (b) are more common, as in alternative leasing methods or in concessionary financing (where a portion of interest may be implicitly charged through higher machine purchase cost, yielding a stated interest rate much below market rates). Therefore, machinery cost calculation formulas should be flexible enough to deal with financing. Furthermore, making expected financing cash flows explicit in the cost analysis helps an operator plan for and manage those cash flows.

As long as all changes in cash positions (net cash flows) are appropriately accounted for, financing arrangements can be handled directly in this machinery cost analysis framework. Because net cash flows arising from income tax savings may be easily overlooked in computing net cash flows over time, it is imperative that income-tax affecting cash flows are separated from those that are not. To accommodate financing, two cash outflow variables are considered. The first variable includes those cash outflows that do not affect income taxes. It is $NDFCF_k$ (for nondeductible financing cash flow). The tax-deductible counterpart is $DFCF_k$. No formulas are presented for the variables because they are user-determined. However, NDFCF is a likely candidate for loan principal payments (loan principal payments are not tax deductible). In that case, two conditions must be met:

Equation 17

$$\sum_{k=0}^{k=K} = NDFCF_k = 0; \text{ and } \quad \sum_{k=1}^{k=K} NDFCF_k = -NDFCF_0$$

Because the financing variables represent cash outflows, if NDFCF is used to represent a loan, $NDFCF_0$ = negative of the dollar amount financed (because it represents inflowing money in year 0). For k = 1…K, $NDFCF_k$ = the dollar amount of the loan principal paid in year k. If NDFCF is used for loan principal, then DFCF should be used for interest payments. These interest payments must be based on interest at the pre-tax rate because their tax-deductibility will be accounted for later.[12] As described, if the pre-tax interest rate selected is [COC ÷ (1-T2)], then inclusion of NDFCF and DFCF in this analysis will not affect the net present value for the machine. It should be noted that COC should always be based on the average after-tax commercial bank rate on conventional agricultural loans, and never on a concessionary loan rate.

If a machinery lease or rental agreement is considered, cash flows must be appropriately accounted for in either NDFCF or DFCF, according to their tax deductibility. For example, rental payments would typically be placed only in DFCF because they are tax-deductible. Also, other cost formulas may require adjustment depending on the financial arrangement. For example, in lease or rental agreements, it is likely that the dealer will cover part or all of repairs. Careful consideration of the amount, timing, tax-deductibility, and effect on other costs, for each cash flow will assist an operator in making the proper formula adjustments. However, in most analyses, such as with traditional bank financing or owner financing, zeroing out NDFCF and DFCF will not affect the results because loan interest rate equals [COC ÷ (1-T2)]. Nonetheless, displaying the financing cash flows may assist in cash flow management.

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[12] *Values for projected principal and projected interest payments may not be readily available. In that case it may be necessary to include another variable (another column in the spreadsheet) which tracks the loan balance, so that each year's interest payment can be properly computed from the prior year's remaining loan balance.*

Income Tax Depreciation

Unlike many financing decisions, income tax decisions affect net present value analyses and the profitability of long-term investments. Consequently, analyzing machinery costs should always consider income taxes. Tax depreciation represents a method of allocating the cost of an asset as a business expense over the life of an asset. Allowable allocation methods are determined by either Congress or the Internal Revenue Service (IRS). Because the timing of tax depreciation rarely matches the timing of economic depreciation net present value is affected. In its simplest form, basis is the amount of cash paid for a machine that has not yet been assigned as a tax-deductible expense (depreciated). When a trade-in is involved in a machine purchase, the basis for the newly-acquired machine is the sum of the cash boot paid and any remaining basis in the machine traded in. When a machine is sold before it is totally depreciated, a basis is said to remain. The difference between the selling price and the basis has tax implications. If that difference is less than the amount of total depreciation taken, it is considered depreciation recapture and is taxed as ordinary income. The portion of the difference (if any) that is greater than total depreciation taken is considered a capital gain, and is taxed at capital gain tax rates. If a machine is sold at less than its basis a capital loss results.

Although capital and ordinary gains and losses are sometimes treated differently under tax laws, at the present time (1996) capital gains for the most part are taxed at the same rate as ordinary income [see the annual Farmer's Tax Guide (Publication 225) from the IRS for additional detail]. The important distinction is that, unlike costs such as fuel and repairs, neither depreciation recapture nor capital gains affect self-employment income. Thus, it is helpful to think of the difference between selling price and tax basis as simply gain, not distinguishing between actual capital gain and depreciation recapture.

One IRS concept that is especially relevant for machinery is the Section 179 expense deduction. In the year that a new or used machine is acquired, some or all of its basis can be deducted as a business expense. Technically, this is not part of income tax depreciation, but it is closely related to it. Presently (1996), the maximum Section 179 annual deduction is $17,500 for each taxpayer. That is, up to $17,500 of current machinery purchases can be expensed in the current year as long as there is taxable income sufficient to offset it. Therefore, the first tax decision to be made for a newly acquired machine is how much, if any, Section 179 expense to claim.

The basis in the newly-acquired machine is adjusted downward by the amount of Section 179 expense taken. The remaining basis is then depreciated according to a preselected schedule. Generally, most farm machinery is considered 7-year property for depreciation methods other than straight-line depreciation. A commonly used depreciation method is the MACRS (modified accelerated cost recovery system) 150 percent declining balance method. Using the midyear convention, this method states that 10.71 percent of the basis is depreciated in the year of purchase (year 0), 19.13 percent in the next year, 15.03 percent the next, followed by four years of 12.25 percent each, and 6.13 percent in year 7.[13]

Let BTBASIS be the beginning tax basis at the time of purchase (year 0), before any Section 179 deduction has been made. Let SEC179 be the amount of Section 179 deduction selected. Let MACRS_k be the kth year's MACRS percentage (for 7-year property, when $k > 7$, $\text{MACRS}_k = 0$). Then, the tax depreciation in year k, TDEPR_k, is

Equation 18

$$\text{TDEPR}_k = (\text{BTBASIS} - \text{SEC179}) \times$$
$$(\text{if } k = \textit{end}, \text{ then } \frac{\text{MACRS}_k}{2}, \text{else } \text{MACRS}_k) +$$
$$(\text{if } k = \textit{begin}, \text{ then SEC179, else } 0)$$

If the beginning tax basis for a machine is $10,000, and the Section 179 deduction is chosen to be $3,000, then the depreciation each year (k = 0 through k = 7) is normally $7,000 times the relevant MACRS value. However, the first conditional statement (the one including MACRS_k) states that in the year of a machine's sale (k = end) only one

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[13] *To be consistent with earlier formulas the purchase year should be year 0, which is also the first year depreciation is claimed. The Farmer's Tax Guide states the year of purchase as year 1.*

half of the normal depreciation is allowed. The last term in Equation 18 makes it clear that the Section 179 deduction is added to the depreciation only in the year of purchase (when k = 0). The remaining tax basis at any year k, $TBASIS_k$, after that year's depreciation has been taken, is

Equation 19

$$TBASIS_k = TBASIS_{k-1} - TDEPR_k$$

When k = 0, $TBASIS_{k-1}$ is defined to be BTBASIS, and in the example, $10,000. In the final year of the analysis, when the machine is assumed sold, a gain (positive or negative) is accrued. In variable format, and moving back to the n notation, gain is described by:

Equation 20

$$GAIN_n = SELL_n - TBASIS_n;\ \text{if } n = \textit{end}\text{, else } 0$$

Income Tax Savings

Several of the individual cash flow items have further cash flow implications in that they represent taxable expenses, and as such accrue tax savings. In this category are fuel and lubrication; labor; repairs and maintenance; property taxes, insurance, and shelter; and the financing variable, DFCF. The deductible expense described in Equation 20, although not directly a cash flow, does belong here because it is tax deductible. As such, it affects taxes paid (but not self-employment taxes) and ultimately affects after-tax cash flows. The income tax savings in any year n (n=*begin … end*), ITS_n, is

Equation 21

$$ITS_n = [(FL_n + LAB_n + RM_n + TIS_n + DFCF_n + TDEPR_n) \times T2] - (GAIN_n \times T1)$$

Net Cash Inflows for Computing Net Present Value

Because the net present value formula deals with net cash inflows rather than outflows, each of the items in the following formula for cash flow in year n, CF_n, with the exception of income tax savings and selling price, enter with a preceding minus sign:

Equation 22

$$CF_n = (-PUR_n + SELL_n - FL_n - LAB_n - RM_n - TIS_n - NDFCF_n - DFCF_n + ITS_n)$$

As a way of summary, each of the variables on the right-hand-side of Equation 22 are described again:

PUR_n = purchase price (will be 0 for n > begin)
$SELL_n$ = selling price (will be 0 for n < end)
FL_n = fuel and lubrication charge in year n (pre-tax)
LAB_n = labor charge in year n (pre-tax)
RM_n = repair and maintenance, adjusted by a personal adjustment factor in year n (pre-tax)
TIS_n = property taxes, insurance, and shelter in year n (pre-tax)
$NDFCF_n$ = non tax deductible financing cash flow in year n
$DFCF_n$ = tax deductible financing cash flow in year n (pre-tax)
ITS_n = income tax savings due to tax-deductible items in year n

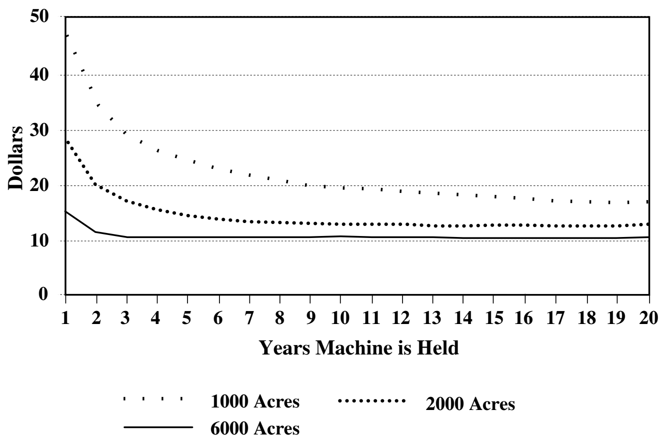
Using the Machinery Cost Analysis Results to Make Decisions

Once the net cash inflows are computed, the net present value (NPV) and inflation adjusted amortized annual cash flow values ($IAACF_n$) are ready to be computed using the formulas described earlier (Equations 14 and 16). NPV or $IAACF_n$ values can be summed across machine operations so that competing machinery investment scenarios, machine operation scenarios, or competing cropping systems can be compared. Following a brief description of how comparisons should be made are three graphical examples that illustrate some typical comparisons.

In general, to accommodate different time horizons across scenarios, and to reduce all comparisons to the present year, alternative machinery scenarios should be compared by examining the $-IAACF_0$ value for each (the negative sign is included to restate negative income as positive costs). Smaller $-IAACF_0$ values are preferred, and are indicative of lower machinery costs. Finally, two additional steps should be taken to make calculated machinery costs more comparable with custom

Figure 9.

Cost per Acre for a Case-IH Combine, at Three Annual Usage Rates (1996 dollars, pre-tax)



rates. First, -$IAACF_0$ values should be divided by units per year (such as acres, hours, or bales). Second, the cost per unit should be divided by 1- T2 to effectively make all per unit costs pre-tax.

Different projection horizons can be examined by merely changing the final year in the analysis and recalculating. That is, K in Equations 14 and 16 can be assigned a different value (along with the proper adjustments for end where needed). By examining K at levels ranging from 1 through 10, for example, inferences can be made about the most profitable length of time to hold a machine. If –$IAACF_0$ falls from K = 1 to K = 10 it means machinery costs are falling when the machine is held for longer time periods. In fact, it suggests that the machine should be held for more than 10 years. On the other hand, if - $IAACF_0$ falls from K = 1 through K = 5, and subsequently rises, it indicates that expected annual machinery costs are higher when the machine is held for more than 5 years. The implication is that the producer should trade the machine after year five.

Example 1: Costs for a New Case-IH Combine across Three Usage Rates

The formulas in this bulletin were used to compute the cost per acre associated with a Case-IH combine with a 30 foot platform purchased new in 1996 for $150,000. Costs are compared across three annual wheat harvesting acreages, 1,000, 2,000, and 6,000; and across 20 trading regimes, at 1 year through 20 years. Field efficiency and operating speed from appropriate tables imply that 7.6 acres are covered per hour. Thus, the 1,000, 2,000, and 6,000 annual acreages are associated with around 132, 263, and 789 annual machine hours, respectively. The first two usage levels would be more typical of a farmer-owned combine, and the third level of a custom harvester. Other assumptions are: a bank loan rate of 0.10, which implies an after tax cost of capital, COC, of 0.06; inflation rate, 0.0245; marginal tax rate (T1), 0.2635; marginal tax rate (T2), 0.40; diesel fuel cost (1996), $0.90 per gallon; and labor cost (1996), $10 per hour. Section 179 expensing deduction was 0 and remaining values were computed with Cross and Perry formulas (Equation 4).

Figure 9 depicts the pre-tax per-acre costs for the combining example just described. Per-acre costs are consistently lower for higher usage rates, regardless of how long the combine is owned. However, per-acre costs for the minimally used machine (1,000 acres) drop dramatically when the machine is held for more than one year. In that case, the farmer may want to hold the machine for 20 years or more. For the mid-usage machine (2,000 acres), cost per acre flattens out after 4 or 5 years, suggesting this may be a good time to trade–especially if timeliness costs were to be made explicit, which could easily offset the marginal reductions in costs associated with holding the combine for more than 4 or 5 years. For the supposed custom harvester (6,000 acres), costs flatten out much more quickly, suggesting the machine should be traded off in 2 years.

Example 2: Costs for a New Case-IH Combine across Three Inflation Rates

Figure 10 shows the costs associated with the Case-IH combine harvesting 2,000 acres per year and at 3 different inflation rates: a) 0.0; b) 0.0245 (the same rate used in the preceding example); and c) 0.0736 (3 times the rate used in the preceding example). Because the cost of capital was fixed at 0.06, (a) represents an increase in the real interest rate from the previous example and (c) represents a decrease. The increased incentives associated with decreased real interest rates, both to purchase a new combine and to trade more often, are readily seen. First, at any holding period length considered, higher inflation rates are associated with lower costs in 1996 pre-tax dollars. This means purchasing a new combine is more attractive with lower real interest rates (here, through higher inflation rates).

Figure 10.

Cost per Acre for a Case-IH Combine (2,000 A/yr.) at Three Annual Inflation Rates (1996 dollars, pre-tax)

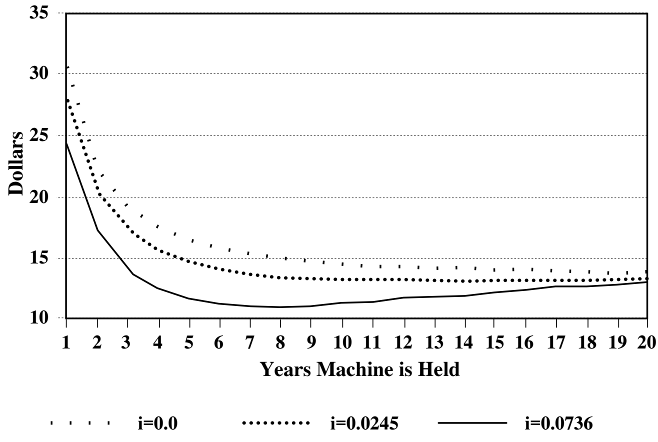
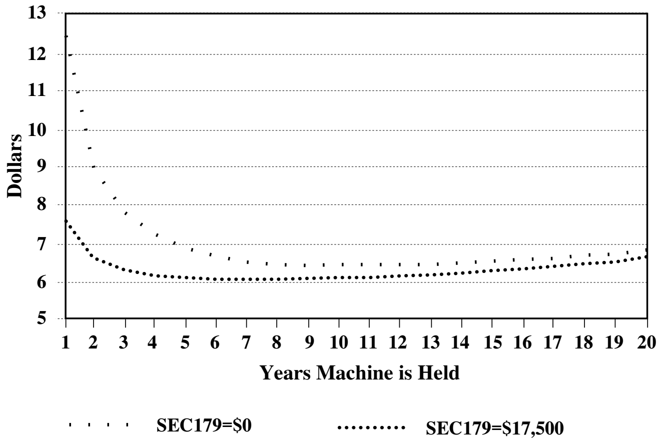


Figure 11.

Cost per Acre for an 8-Row Planter, with and without Section 179 Deduction (1996 dollars, pre-tax)



Second, higher-inflation cost curves flatten more quickly and begin to rise substantially for longer holding periods. This means combines should be traded more often with high inflation rates.

Example 3: Costs for a New 8-Row Planter with and without Section 179 Expensing Deduction

Figure 11 depicts the per acre cost for a new 8-row (30 inch) planter purchased in 1996 for $20,000 and used on 750 acres per year. Tax, discount, and inflation rates, as well as unit costs for fuel and labor, are the same as in Example 1. Field efficiency, fuel consumption, and ground speed are taken from the appropriate tables. Because fuel and labor were charged to the planting operation, a tractor was assumed to be rented at $15 per hour. The figure clearly shows the affect of using the Section 179 expensing deduction. With the deduction, costs are lower across all holding periods, and especially so for holding periods of only a few years. Furthermore, taking the Section 179 deduction implies that a producer should trade sooner, in this case at 5 to 6 years compared to 8 to 10 years without taking the deduction.

Conclusion

This bulletin has developed a framework for calculating expected machinery ownership and operating costs: repairs and maintenance, fuel and lubrication, insurance and property taxes, depreciation, income taxes, and opportunity cost on investment funds. Many machinery cost calculations depend on current list price, a value readily derived from current market value using remaining value formulas. Traditionally, remaining value was considered determined by age. This bulletin describes an alternative process that allows usage rate to affect remaining value, which should more accurately assess future market value for machines used at different levels of intensity. Accurate assessment of future value is important because future value determines economic depreciation which affects annual machinery costs. Future value also determines potential taxable gain when a machine is sold, and hence income taxes.

Machinery investment is associated with widely varying annual cash flows because several cost components vary with age, and especially because income tax depreciation rarely matches economic depreciation. In this paper, expected future cash flows are first discounted to the present using net present value analysis. Net present values are then amortized, resulting in annual machinery costs that can readily be compared across different machinery complements and alternative holding periods, as well as with custom rates. The result is a procedure that can assist a producer in selecting a machinery complement that minimizes costs. It also suggests when a particular machine should be traded off.

Income tax considerations are especially important in machinery cost analyses. The formulas developed in this paper explicitly accommodate income tax rates, tax depreciation rates, and the Section 179 expensing deduction. Consideration of the expensing deduction alone is shown to substantially affect the optimal time period over which a machine should be owned.

Although financing decisions should typically not affect machinery decisions, financing formulas have been included so that alternative financing arrangements, such as leasing, or concessionary loans, can be considered. Also, making explicit the financing cash flows should assist cash flow management.

Because the formulas provided in this publication can readily be developed in a computer spreadsheet, this bulletin should help producers make machinery cost calculations, and ultimately the profit maximizing decisions which follow. The development of such a spreadsheet will enhance understanding of the concepts presented. Further, those concepts are more important than the exact values falling out of the calculations. Finally, formula-based cost calculations should always be validated against personal experience. Where experience suggests calculations should be modified, an understanding of the principles and mathematics underlying the formulas will assist in making reasonable modifications.

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