CHAPTER 6

MACHINERY, EQUIPMENT, AND BUILDINGS: OWNERSHIP COSTS

INTRODUCTION

The objective of this section is to discuss issues and procedures related to estimating the cost of capital assets. Capital assets are factors of production that are not used up during a single production period, provide services over time, and retain a unique identity. The term **durable asset** is often used to describe **physical capital** because the word durable denotes not temporary or long-lived. Many durable assets such as machinery or buildings have reduced service capacity due to use and/or time. Some capital assets (breeding livestock, tile drains, windbreaks) may even be completely worn out or used up over a period of years.

There are many examples of durable assets in crop and livestock production operations. Land is perhaps the most significant durable factor of production for crops. It is an example of a unique nondepreciable durable asset. Land involves a point investment with a relatively constant flow of services over a very long, perhaps infinite, period. Land improvements such as terraces and land leveling may also involve a flow of service over an infinite period or in some cases provide service over a finite length horizon. In this latter case, these improvements would be classified as a durable factor of production (details associated with the costing of land are presented in Chapter 7). Similarly, the right to draw irrigation water from a particular stream is a capital (durable) asset in the sense that water can be withdrawn year after year. The primary focus of this section is on durable inputs, other than land, used in crop production. The most common durables in crop production are machinery, irrigation equipment, crop storage structures and equipment, and machinery storage structures. In livestock production the most routine durable inputs are the buildings and equipment used to house, care, and feed animals, and dispose of their waste. Breeding livestock are also considered durable inputs because they produce a flow of products (milk, offspring, wool, and so forth) and/or services (such as those provided by draft or riding animals) over multiple periods. Many durable inputs are used in multiple enterprises and require allocation of the ownership and use costs across the alternative production processes. A more complete discussion of such joint costs is contained in Chapter 9 entitled Joint Costs, General Farm Overhead, and Rights to Produce and in the final section of this chapter.

PRODUCTIVITY OF DURABLE ASSETS

As discussed in Chapter 2, a durable asset may provide different levels of service depending on its condition as represented by age, amount of previous use, service enhancement, and maintenance performed. It is common in preparing cost of production estimates to assume that durables such as machinery and buildings provide a constant quality of service over their lifetime with regular maintenance. This assumption is more appropriate for facilities and equipment that is properly maintained than for breeding livestock, perennial crops, and some types of land improvements. For these capital inputs and for machinery with highly variable productivity over time, the procedures discussed in Appendix 6A and Chapter 10 are more appropriate.

Chapter 6. Machinery, Equipment, and Buildings: Ownership Costs

TYPES OF COSTS

The major types of costs associated with asset ownership and use are the opportunity cost associated with the financial capital invested in the asset, reductions in value due to use and/or time, and changes in the market value of the asset during the period it is held. Other costs such as property taxes, housing, and insurance are generally much smaller.

Changes in Market Value

Changes in the market value of an asset can occur because of changes in its service capacity (quantity, quality, and reliability of service provided) and/or because of changes in the market price of the services it provides. If V_1 is the value of the asset at the end of a period and V_0 is the value at the beginning of the period, then the change in market value is equal to $V_0 - V_1$. This change in market value ($V_0 - V_1$) is called **economic depreciation (ED), which is defined as the change in the asset's present value as time passes, given the remaining, but shorter series of earnings and the given economic rate of return**. For an asset whose value declines over time, ($V_0 - V_1$) will be a positive number and reflect a positive cost. Reductions in the service capacity of an asset are considered first under the general topic of depreciation resulting from reductions in service capacity.

Depreciation Resulting from Changes in Service Capacity

The reduction in service capacity associated with time and use is a major ownership cost for most durable inputs. The flow of services a durable provides may decline over its life because of three components—time, use, and obsolescence. Among types of durables there is considerable difference in the relative importance of each of these components in explaining remaining values of an asset over its life. Once a specific asset is placed in use, the remaining value is dependent upon actual use, age, and technological change. For assets with active markets, this depreciation often can be observed in a reduced market value. If data are not readily available on the value of the remaining service potential of an asset during each period of its life, estimates of depreciation must be made. A particular level of remaining service potential is sometimes called the **use value** (UV) of an asset or the **remaining value** (rv) of the asset. The use value of an asset depends on many factors including the type and age of the asset, its expected useful life, its previous use, prior maintenance, housing provided, care exercised by the operator, and so forth. This multidimensional characteristic vector describing the use value of an asset is often approximated by an estimate of its remaining hours of "normal" service life where normal is a vague description of some modal type of service. The most common assumption for economic costing purposes is that the total decline in the value of potential service from the time the machine is purchased until it is sold is distributed evenly over the life of the asset. This is called **straight-line depreciation** and is given by **dividing the decline in use value over this total time by the number of years or periods**. This is given by

$$D_{sl}(j) = \frac{UV_0 - UV_n}{n}$$

where D_{sl} (j) is straight-line reduction in use value (depreciation) in the j^{th} year, UV_0 is the use value at the beginning of the first period, UV_n is the use value at the end of the n^{th} period, and n is the number of periods. Because the asset is held over the entire period, one can ignore interim declines in value (or profits) and consider the asset's entire life as a single decision unit (Levy and Sarnat). Straight-line depreciation usually assumes some fixed level of usage per year (which adds up to total use over several years) so that depreciation per year is dependent only on the passage of time. It is important if this annual level of use changes to modify both the total and the annual rate of depreciation.

Farm machinery, in particular, may not have this straight-line pattern but may have larger declines in remaining value during early periods of life (Robison and Barry, 1996: Chapter 9) due to time and obsolescence. A common approximation to this nonlinear pattern is the sum-of-the-years method of computing depreciation. This pattern is not necessarily recommended by this Task Force but illustrates well a non-linear pattern. The total depreciation over the life of the equipment is computed using the following formula for each year where n is the years the machine is owned between purchase and subsequent sale.

$$D_{sy}(j) = \frac{(n+1-j)}{\left(\frac{n(n+1)}{2}\right)} (UV_0 - UV_n) .$$

In this formula, D_{sy} represents sum-of-the-years reduction in use value (depreciation) in the j^{th} year. This method, as with straight-line depreciation, while attempting to adjust for nonlinear changes in use-value, assumes that for given values of UV_0 and UV_1, depreciation each year is dependent only on the passage of time and does not take into account the effect of the amount of use in an individual year.

Example: For comparison of the two methods consider a new tractor with a list price of $70,000 where it is assumed that use value is measured in dollars. Assume that at the end of each year the tractor has the total hours of use with remaining value as shown in Exhibit 6.1. Also assume that the price for a tractor with a given age and hours of use is constant in real dollars. Assume that the farmer is planning on selling the tractor at the end of five years. Notice that in this example the decline in remaining value is related to time and not just use in terms of hours.

EXHIBIT 6.1

Remaining Value ($)	Age	Total Hours of Use	Depreciation Straight-line (SL)	RV (SL)	Depreciation Sum-of-the-years (SY)	RV (SY)
70,000	0	0		70,000.0		70,000.00
47,586	1	500	7,107.8	62,892.2	11,846.33	58,153.67
43,040	2	900	7,107.8	55,784.4	9,477.07	48,676.60
39,535	3	1,500	7,107.8	48,676.6	7,107.80	41,568.80
36,821	4	1,900	7,107.8	41,568.8	4,738.53	36,830.27
34,461	5	2,400	7,107.8	34,461.0	2,369.27	34,461.00

The total decline in use value is $35,539 (70,000 - 34,461). Straight-line depreciation assumes the machine has a constant decline in value of $7,107.80 per year. This gives the remaining values in the RV Straight-line column. The value at the end of five years is the same as the actual pattern of remaining values, but the values for each of the years are very different. Remaining values computed using sum-of the-years depreciation are in the last column of the table. The pattern is not uniform as with straight-line depreciation and seems to mimic the time pattern of remaining value somewhat better. As long as the machine is held over the entire period, the economic costs of either method over the five-year time horizon will be the same as is seen in the section entitled Procedures for Cost Estimation.

Another common technique for estimating depreciation, which is also acceptable for tax purposes, is the declining balance method. The declining balance method implies a geometric decline in value over time. A fixed rate of decline is applied to the value of the machine at the end of each year. The depreciation is computed recursively as follows

$$
\begin{aligned}
D_{db}(1) &= (UV_0)\ (rd) \\
UV_1 &= UV_0 - D_{db}(1) \\
D_{db}(2) &= (UV_1)\ (rd) \\
UV_j &= UV_{j-1} - D_{db}(j) \\
D_{db}(j) &= (UV_{j-1})\ (rd)
\end{aligned}
$$

where rd is a rate of depreciation expressed as a percent of the useful life of the machine and UV_j is the value of the machine at the end of the j^{th} year. This can also be written as

$$UV_j = UV_0(1 - rd)^j .$$

With this method, the machine will never reach a zero salvage value and so it is not as applicable for estimating economic depreciation unless it is truncated. An alternative that is often used in practice is to use the double declining balance method of depreciation for the first few years of an asset's life and then switch to a straight-line method for the remaining years when the annual depreciation computed from the double declining balance method is less than the straight-line amount. This avoids the problem of the salvage value only going to zero in the limit.

Price Changes

An asset may also change in value due to changes in the price of a unit of the asset's service. For example, a steep rise in the price of sweet corn may lead to a rise in the price of used sweet corn harvesters, regardless of their remaining service capacity. Or, a drop in the price of gasoline may lead to a drop in the price of ethanol distillation equipment. The point being that an asset changes in value because the net present value of its expected services changes.

To clarify the difference between the reduction in service capacity and the total change in the value of an asset during a period, consider dividing this total change into two parts: reduced service capacity and price changes. This is most easily illustrated if use value and prices are measured in a single dimension so that there is no need for the multidimensional characteristic vector describing the asset. The simplest case is to measure the service capacity of the asset in terms of the number of available hours of potential use. If the market price of a unit of asset service at the beginning of the period is given by p_b, the beginning service potential (or remaining hours of potential use) by UV_b, and the ending service potential by UV_e, then the value of the amount of service reduction is given by

$$\begin{aligned} \textit{Cost of service reduction} &= (p_b)\ (\textit{amount of service reduction}) \\ &= (p_b)\ (UV_b - UV_e) . \end{aligned} \qquad \textbf{(6.1)}$$

The change in value due to price changes is called the price change cost and is given by

$$\textit{Price change cost} = UV_e(p_b - p_e) \qquad \textbf{(6.2)}$$

where UV_e is the service potential at the end of the period and beginning and ending prices of the service potential are given by p_b and p_e, respectively. Total costs due to service reduction and price changes are given by the beginning of period value minus the ending value of the asset or

$$
\begin{aligned}
\textit{Service reduction cost} + \textit{price change cost} &= \textit{economic depreciation} \\
&= ED \\
&= \textit{beginning value} - \textit{ending value} \\
&= V_0 - V_1
\end{aligned}
\qquad \textbf{(6.3)}
$$

where V_0 is value of the asset at the beginning of the period and V_1 is the value at the end of the period. The decline in the total market value of an asset in a particular year is thus a result of the physical and technical factors as well as the changes in the market price of a unit of the asset's service. This **total change in the total market value of an asset is economic depreciation** because it represents the decline in the value of the asset over the period.

For a farm or group of farms in which records are used as a source of data for cost estimates, economic depreciation (year-to-year declines in the estimated market value of the asset) can be used conceptually as an estimate of the service reduction and price change portion of ownership costs if such market value estimates can be obtained and inflationary impacts separated carefully. For a particular asset of a given age and condition, this approach could result in different estimates of physical and market depreciation depending upon the durable asset market in that year. For some assets, market values are difficult to secure. Also, assets such as buildings are attached to the land asset. Market value changes in such assets not only may be difficult to determine but also may not be reflective of their true economic worth to another user because of their immobility.

When beginning and ending values for a durable asset or its services are not easily available on a year-by-year basis, another method to estimate service reduction and price changes is needed. The most common method does not rely on annual market value changes, but estimates a constant annual cost assuming an expected rate of use and a salvage (remaining) value based on projected use and obsolescence. The most common assumption on the decline in remaining value per period is that it is constant over the life of the asset or constant per hour of use as with straight-line depreciation. This method is particularly useful for projected CAR estimates, but can also be useful in record-based estimates when the market values of assets are difficult to estimate. Year-to-year depreciation differences are not important in such cases because with most economic cost estimation techniques only an average year cost of depreciation is needed. This method is discussed in more detail in the subsection entitled Procedures for Cost Estimation.

Depreciation methods commonly used for tax purposes are not normally used in developing CAR estimates because they do not necessarily reflect the economic costs of owning and using an asset and are thus irrelevant to the economic costing process. Income tax impacts and their equivalent costing are also not included in this discussion. Tax shelter impacts on durable asset costs should be estimated through the use of capital budgeting for the assumed ownership period of the asset. Tax benefits can then be credited in the after tax flow of the costs. Once present values on an after-tax basis are estimated and amortized, they can be converted to an equivalent before-tax basis. These other forms of depreciation may be important to decision makers who are owners of durable assets for financial reasons but are not important for computing economic costs and returns. A more complete discussion of the tax impacts of durable ownership is contained in Watts and Helmers (1981) and Leatham and Baker.

An important assumption underlying the estimation of depreciation is a given estimate of annual use that exhausts the life of the asset over a specified period. This assumption of a given use per year exhausting an asset's life is sometimes forgotten, resulting in a concept of depreciation which is only age related. For purposes of economic costing as an average over an asset's life, the distinction of age and use causes of depreciation is not particularly important. Increased use of a durable asset in a year will reduce the life of the asset which, if remaining values are impacted only by use, will not impact depreciation cost per hour of use. Because remaining values depend on both age and use, however, it is important to insure that age and annual use assumptions are compatible with the salvage values used. In addition, opportunity costs per hour of use are reduced by greater use as will be seen in the next section.

Opportunity Costs

The second ownership cost associated with durable assets is the opportunity cost of the financial capital invested in the durable. This opportunity cost of ownership is often called **opportunity interest** because it is related to the interest rate available on financial capital. For depreciable assets, this opportunity interest cost is generally second to depreciation in magnitude. For record-based CAR estimates where an individual farm's cost is estimated for a particular set of assets with specific ages, interest costs should not be secured directly from paid interest because (1) an inflation-free interest cost is usually needed and (2) only a portion (or none) of the asset value is financed. Hence, for record-based data an opportunity cost on the market value of the asset should be used. For nonrecord-based estimates, opportunity interest cost is estimated on an average-year (or annuity) basis because year-to-year differences are unimportant to an annual average interest cost. Because the level of annual use impacts time of replacement, the assumption or determination of annual use is important to this costing process. The replacement time affects the length of time the asset is in use, and thus annual interest costs.

Market Value, Salvage Value, and Remaining Value

The market value of an asset is what it would sell for currently if placed on the market. The market value is determined by the service capacity of the asset and the value of that capacity to firms who utilize it in the production of other goods or services. The **salvage value** of an asset is the **market value that remains at the end of the costing period**. This salvage value will change based on the length of time the asset is held, its level of use, how well it is maintained, and changes in the market price of the asset’s services. The **remaining value** of an asset can be expressed as the **ratio of the current market price** of the asset in its current age and condition **to the initial purchase price of the asset**. This is often expressed as a percentage. The estimated values of aged farm machines are established at farm sales, at established machinery auctions, and by farm equipment dealers selling used equipment they have taken in trade. These market data are commonly summarized in “guides” and “bluebooks”. There are significant differences in remaining value for various makes and models of a given type of machine. When data on specific equipment or buildings are available, they can be used to estimate market value, salvage value, and remaining value. In most situations, specific data are not available, and other estimates must be used.

Data on actual purchase prices for new equipment frequently are not available except for specific transactions. The most frequently used proxy is the list price of the equipment as published in the *Official Guide* of the North American Equipment Dealers Association (NAEDA 1993, 1996). While this may overstate purchase price, it may not cause serious error if similar list prices are used to value used equipment. A common adjustment used by a number of universities for the difference between list price and purchase price is 15%, though this is a very rough number. Engineering estimates or dealer/contractor quotes are usually used as purchase prices for buildings, silos, fencing, tiles, and terracing. Some information on these prices may be available from real estate appraisal manuals such as *Agricultural Building Cost Guide* published by Boeckh, New Berlin, Wisconsin. An alternative is to use direct producer surveys.

Data on remaining values for equipment are most often obtained using estimates prepared by the American Society of Agricultural Engineers (ASAE D497.2 MAR94 in ASAE [1997]). A set of estimates used for many years gives the remaining values of four classes of equipment as a function of the years of use. The equations are reported in Table 6.1.

TABLE 6.1 Remaining Values as a Percent of List Price

Class of Equipment	Remaining Value as % of List Price at the End of Year n
Tractors	$68(0.920)^n$
All combines, cotton pickers, self-propelled windrowers	$64(0.885)^n$
Balers, forage harvesters, blowers, and self-propelled sprayers	$56(0.885)^n$
All other field machines	$60(0.885)^n$

Source: ASAE 1997.

These estimates were prepared initially by Wendall Bowers using data from the Spring 1965 issue of the *Official Guide* of the National Farm Power and Equipment Dealers Association. The estimated equations were modified by members of the machinery management committee of the ASAE in 1971; they have not been modified since. These estimates are based on adjustments to the declining balance method of computing depreciation to account for large first-year declines in value. The declining balance formula for remaining value is as follows

$$rv_n = (1 - \frac{rt}{life})^n \tag{6.4}$$

where rv is the remaining value (expressed as a decimal), rt is the declining balance rate (1 for straight-line, 2 for double declining, etc.), and n is the number of years since purchase. The declining balance method assumes that the salvage value of the machine is included in the remaining value and never reaches 0. For example, if rt is 1.6 and the expected life is 20, the remaining value is $(0.92)^n$. This number is multiplied by the purchase price to get the value of the asset at a given point in time. Thus a machine with a purchase price of $50,000 would have a value of $32,954.076 [$(50,000)(.92)^5$] after five years. The formulas in Table 6.1 adjust this declining value by a constant to reflect large first-year depreciation. For tractors this constant is

68. The numbers in Table 6.1 must be multiplied by 0.01 to obtain rv as a decimal. Based on a tractor with a purchase price of $50,000, the remaining value after five years is $22,408.77 [(50,000)(68)$(.92)^5$(0.01)].

The estimates in Table 6.1 are based on data that are 30 years old. In addition to their age, these estimates have a number of problems related to markup values, geometric depreciation patterns, and constant reconditioning costs (Cross and Perry, 1995). Bowers (1992, 1994) has developed updates to these initial estimates based on more recent data but these updates have not been adopted by ASAE. The latest values as reported by Bowers (1994) are given in Table 6.2.

TABLE 6.2 Remaining Values as a Percent of List Price

Class of Equipment	Remaining Value as % of List Price at the End of Year n
Tractors	$67(0.940)^n$
Combines	$65(0.93)^n$
Cotton harvesters	$62(0.92)^n$
Windrowers, mowers	$67(0.90)^n$
Forage harvesters	$56(0.90)^n$
Balers	$66(0.92)^n$
Planters, tillage tools	$62(0.96)^n$

Source: Bowers 1994.

Recent papers by Cross and Perry (1995, 1996) estimate alternative remaining value functions based on auction sale prices reported in the *Farm Equipment Guide* published by Hot Line Inc. The data cover equipment manufactured from 1971 to 1993. Using a Box-Cox functional form they estimate remaining value as a function of age, use, care, manufacturer, auction type, region, national real net farm income, and the prime interest rate. Age and usage data as well as remaining value were transformed using the Box-Cox procedure while other variables were entered linearly. The estimation allowed for lags in the income variable. All prices were deflated using the Producer Price Index. Expressions suitable for use in cost estimation are reported in Table 6.3.

TABLE 6.3 Remaining Values as a Percent of List Price

Equipment Type	Remaining Value as % of List Price with Given AGE and Annual Hours of Use (AU)
Combines	$rv = [0.94534 - 0.04551\ AGE^{0.87} - 0.00182\ AU^{0.72}]^{2}$
Swathers	$rv = [0.94154 - 0.04564\ AGE^{0.5}]^{5.26}$
Balers	$rv = [0.95433 - 0.05939\ AGE^{0.57}]^{2.78}$
30-79 HP Tractors	$rv = [0.88507 - 0.05827\ AGE^{0.46} - 0.00018\ AU^{0.9}]^{2.17}$
80-149 HP Tractors	$rv = [0.97690 - 0.02301\ AGE^{0.76} - 0.0012\ AU^{0.6}]^{3.85}$
150+ HP Tractors	$rv = [1.18985 - 0.22231\ AGE^{0.35} - 0.00766\ AU^{0.39}]^{2.22}$
Planters	$rv = [0.80414 - 0.01939\ AGE^{0.89}]^{1.96}$
Plows	$rv = [0.61135 + 0.47309\ AGE^{-0.95}]^{1.61}$
Disks	$rv = [0.45198 + 0.60697\ AGE^{-0.85}]^{2.04}$
Manure spreaders	$rv = [1.29956 - 0.45113\ AGE^{0.25}]^{2.22}$
Skid steer loaders	$rv = 0.88302 - 0.2549\ AGE^{0.05} - 0.00002\ AU^{1.31}]^{1.96}$

Source: Cross and Perry, 1995.

The ASAE has adopted further reduced forms of the Cross and Perry (1995, 1996) equations beginning with the 1997 edition of the standards. These equations are reported in Table 6.4.

The Task Force recommends the set of equations in Table 6.4 be used for estimating remaining value.

All of these remaining value estimates are in real terms. Thus they represent the remaining value that a new item of equipment would have at a certain age assuming that equipment prices do not rise relative to the list price of the equipment. If an analysis is done in nominal terms, these estimates must be adjusted for inflation.

Salvage values for use in computing depreciation are usually determined using remaining value equations and an assumed economic life for the particular class of equipment. This salvage value is then used as the market value at the end of the assumed life. There are no firm guidelines for assumed years of use for different types of equipment. Common assumptions for tractors are between 10 and 20 years, whereas the assumed life for most other equipment other than plows and disks is usually shorter. The remaining value functions for plows and disks are very flat after about 10 years, although plows have lower annual depreciation.

TABLE 6.4 Remaining Values as a Percent of List Price

$$RV_n = 100[C_1 - C_2 (n^{0.5}) - C_3(AU^{0.5})]^2$$

RV_n remaining value at the end of n years of age
AU annual hours of use

Equipment Type	C_1	C_2	C_3
30-79 HP Tractors	0.9809	0.0934	0.0058
80-150 HP Tractors	0.9421	0.0997	0.0008
150+ HP Tractors	0.9756	0.1187	0.0019
Mowers	0.7557	0.0672	--------
Balers	0.8521	0.1014	--------
Combines	1.1318	0.1645	0.0079
Swathers	0.7911	0.0913	---------
Plows	0.7382	0.0510	--------
Disks	0.8906	0.1095	--------
Planters	0.8826	0.0778	--------
Manure spreaders	0.9427	0.1111	--------
Skid steer loaders	0.7858	0.0629	0.0033

Source: ASAE 1997.

Remaining values for buildings, silos, tile drains, fencing, and so forth are difficult to estimate in any general fashion because they are often specific to a particular operation. A common approach is to assume a fairly long useful life and a minimal salvage value.

Maintenance Costs

The **maintenance costs** of holding a durable asset are the expenses required to maintain the service potential of the asset at a reasonable level and to extract services for a single time period. Activities associated with these costs usually are not viewed as enhancing the service capacity of the capital asset in any significant way when determining its end-of-period value. Fuel, lubrication, and repairs are common examples of maintenance costs for durable equipment. If major repairs which extend the lifetime of the asset are projected when the asset is purchased, these should be included in the estimate of annual costs and an appropriate adjustment made to the salvage value. For record-based CAR estimates, such major repair expenses in a particular year can be a problem because there is inadequate knowledge over what period of time such costs should be allocated. Because costs such as fuel, lubrication, and repairs often involve the use of expendable inputs, hired services, or operator labor, it is common in computing the costs of owning and operating a piece of durable equipment not to include these costs in the section of the report on allocated overhead, but rather to include them in the operating costs section. As discussed in Chapter 2, Appendix 2C, and by Burt (1992) it makes some sense to combine all the costs of owning and operating the asset into one cost and income stream. This is particularly important in situations where the time patterns of economic depreciation and maintenance are variable.

Other (Time) Costs

Property taxes, storage or housing, and insurance are other costs attributable to the ownership of durable inputs. These costs are typically included in the allocated overhead portion of the estimates. As with maintenance, they can be combined with economic depreciation and opportunity interest to create a stream of total ownership and use costs over time.

ESTIMATING THE COSTS OF MACHINERY, BUILDINGS, AND EQUIPMENT

There are two general approaches to estimating ownership costs of durable assets. The first is to assume ownership of the asset by the producing firm. The second is to use the cost of leasing a durable asset as a measure of the ownership cost.

Estimating Costs Assuming Ownership

The two major ownership costs, economic depreciation (changes in service capacity and its price) and opportunity are often combined into a single annual cost using annuity formulas. The annualization process is a subset of equivalent capital budgeting approaches (Bierman and Smidt; Robison and Barry, 1996) for describing lifetime costs and/or returns (present value, future value, and amortized or annual value). Because the determination of economic costs involves only the estimate of an annual cost, year-to-year changes in asset market values, nominal interest costs, and debt retirement are not as important. These issues may be relevant to individual decision makers who are concerned with cash flow and balance sheet changes resulting from asset purchases, but they are not as critical for estimating CARs of individual enterprises.

Minor ownership costs may include property taxes, insurance and housing. They are usually estimated using observed tax and insurance rates and estimated asset values. Storage may affect asset condition, but asset condition does not impact the storage space required. The annual ownership cost for storage of an asset can be estimated as for other durables and costs allocated proportionately by space required.

As discussed earlier, record-based data are another source for estimating the depreciation portion of ownership costs using reported economic depreciation (year-to-year declines in market value). The difficulty is that few record keeping systems keep track of market as opposed to book values. This approach is more useful if the records contain accurate information on machine specifications, age, and use patterns so that data available from “guides” and “bluebooks” can be used to establish market value. Estimates from guides are most appropriate when there is an active local market reflecting frequent sales of machinery and equipment. Depreciation reported for income tax purposes should not be used for economic cost and return (CAR) estimation. Farm records are also a source of ownership costs relating to property taxes and insurance that are paid annually.

Lease and Custom Costs

A second general approach to the estimation of annual durable costs is to use lease and custom charges, either as a substitute for the above ownership cost approach or where lease or custom use is common. A lease or custom charge for a durable input embodies the above-described depreciation factors (age, use, and obsolescence), interest on invested capital, and other ownership costs. Custom charges may also, however, include inputs such as labor, which must be separated from the custom charge to isolate the cost of the durable service. This is particularly important when some labor associated with the machine operation is performed by the farm operator and some by the custom operator. Leasing costs are likely to be based on hours or acres of use. These costs per hour can be directly translated to an annual enterprise cost through the assumption of a particular usage per year. However, constructing CAR estimates using leasing charges requires good knowledge of the hours used by each enterprise. In addition, for producers who are large enough to take advantage of economies of scale in the use of durable equipment, the cost of leasing may be higher than the cost of owning and operating the same equipment. For example, a large-scale hog operation may be able to justify the cost of its own trucking fleet with lower costs than leasing the same tractors and trailers. In other areas there may be a short-run excess supply of custom operators due to other producers who perform custom work on the side to increase income and spread overhead costs when excess machine time is available. In these situations, the cost of leasing may be less than the cost of ownership, but only for short periods. The availability of custom operators may also be a legitimate concern. If most of these are other producers who perform custom operations during slack periods, there may be problems in getting operations performed in a timely manner. The bottom line is that cost of production estimates should reflect the cost of providing the needed service (appropriate quality and timeliness) at the minimum cost over a long-run time period.

> ***The Task Force recommends that where an active market for the leasing of assets exists and there is good knowledge of the use of a leased asset by enterprise, and there are no particular benefits to asset ownership, the ownership costs derived from leasing rates be the primary approach to estimating costs.***

CAPITAL ASSETS AND NATURE OF THE ESTIMATES

Projected and historical CARs sometimes are constructed utilizing cost records of one or several farms using the specific durable assets existing on those farms. There are two approaches to find the cost of using those durable assets. The first is to use market values of the specific durable assets on that farm or groups of farms in the estimation of ownership costs. This approach has the advantage of representing "actual" or current costs incurred in production, but it has the potential disadvantage of not representing durable asset costs adequately in a longer-run perspective. For example, durable assets used in the production of a low profit or minor enterprise may have low current market value, but a higher use and replacement value. The use of this low market value may result in a uniquely low cost of durable assets for that enterprise.

Using a group of farms, one might expect that across those farms there would be a range in the ages of their durable assets used for this type of enterprise. However, for small or low-profit enterprises, a major proportion of a group of farms may be using durable assets that have been largely depreciated. An example of this is a small livestock enterprise using heavily depreciated buildings and equipment.

Because of these problems, a second approach when using farm records is to utilize the type and size information on durable assets secured from records, but to estimate costs based on replacement costs of those assets. This is a better approach in estimating long-run costs; however, it still has a disadvantage. It may well be that a farmer or group of farmers are utilizing older depreciated equipment of a particular size for a specific enterprise which would not be the case if those farmers were to plan asset purchases and enterprise mixes in a "fresh" or longer-run sense. Thus, data from farm records on specific assets may involve serious suboptimal assumptions for minor enterprises. A third alternative would be to assume that farmers continually replace old equipment with used equipment of a similar type. This may reflect more accurately the age composition of equipment on farms but may not be feasible given limited information on market prices of used equipment.

Cost and return estimates developed in a synthetic manner, in which a determination of the appropriate durable asset mix is made, attempt to resolve some of the above problems. However, assumptions regarding durable asset mixes to be used in the production of an enterprise can be faulty unless very carefully determined. In particular, when CAR estimates are specified involving either a single enterprise or enterprise mixes it is important that the mix of durable assets be optimized before attempting cost analysis. Quite often CARs estimated in this synthetic manner focus on only one enterprise; however, when farms are involved in two or more enterprises, the lack of asset optimization can reduce the applicability of the estimates. Optimization can either be carried out formally using mathematical programming for multiple time periods, or simply approximated using partial budgeting and several tractor and machine combinations.

> ***The Task Force recommends that when CAR estimates are constructed synthetically using durable asset complements, this durable set be optimized for the assumed enterprise size***.

The question often arises, particularly when preparing historical estimates, whether to use the market price of a new asset with a new expected life or the market price of a used asset, similar to the age of those typically traded on the market, with an expected life based on the used purchase and prior use. To the extent that the annualized total cost per hour of use (including maintenance) may be different for a new and a used machine, the choice is not immaterial. This may be particularly important if the new and used machinery markets are in disequilibrium. Over a long time period, these differences should even out given tendency of new and used markets to settle into an equilibrium pattern. In the shorter run, however, estimates for a producer who is using mostly used equipment may be more accurate using purchase prices for new as compared to used equipment. The repair cost equations in Chapter 5 and the remaining value equations in this chapter are based on list prices. Thus, list prices for new equipment must be used for these computations. Once the salvage value for a new machine that will be the appropriate number of years old when the current used machine is to be sold has been determined, the current market price and expected remaining age can be used to determine the capital costs of the used machine. And as discussed in Chapter 5, an annual repair cost for this used machine can also be determined. The Task Force suggests that most CAR estimates be developed using prices for new equipment given that better data is usually available for these machines. In situations where the new and used markets are clearly out of equilibrium or in cases where a producer has a unique set of used machines, the Task Force encourages the use of data that best represents the situation at hand, whether new or used.

The Task Force generally recommends using the price, expected age, and expected salvage value for new equipment in computing capital service costs. In situations where the new and used markets are not in equilibrium and market prices for used equipment are used as appropriate, the Task Force encourages the preparer to include a detailed description of the assumptions made and the calculations used.

ENTERPRISE SIZE AND DURABLE ASSETS

For relatively small enterprises, the use of budgeted ownership costs for durable assets should be seriously questioned because such enterprises may not fully utilize purchased durable equipment. For these situations, the preferred approach is to estimate costs assuming the leasing of durable assets as opposed to the determination of depreciation, opportunity cost, repairs, property tax, and housing costs. In some farming situations, custom operations are also common, and this should be considered carefully as an alternative to estimating ownership costs of those durable assets for small farms and enterprises, particularly when the costs of leasing and custom use are less than ownership.

The Task Force recommends that when CAR estimates are constructed for relatively small enterprises or for assets that are infrequently used, leasing costs as opposed to estimation of ownership costs for those assets should be used.

TIME POINT AND INFLATION

The issue of inflation has particular relevance to the estimation of durable costs. If only annual inputs were used in the production of agricultural commodities, inflation would be of far less importance to the costing process. Because durables involve multiperiods, inflation has an impact on interest rates, asset values, and returns.

In a capital budgeting analysis of investments, it is obvious that a specific time point is required. Also, in economic feasibility analysis of durable inputs, it is well understood that time points are important in the discounting analysis, not only to the return flow but the cost flow. In CAR estimation, which is a subset of capital budgeting, the CAR estimate must be constructed explicitly in reference to a time point. Returns and costs must all be adjusted to the same time point. The issue of appropriate time points for evaluating CARs is complicated further by the consideration of inflation. Thus, these two conditions (inflation and no inflation) are discussed separately.

No Inflation

Under conditions of no inflation and linear depreciation, annual durable cost estimates are constant across the asset's life. These estimates are usually expressed on an end-of-year basis. This is because the typical depreciation and opportunity cost estimation process implies an end-of-year time reference cost point. With no inflation, the nominal interest/discount rate is identical to the real discount rate.

Inflation

With respect to the costing of durable inputs, inflation impacts new asset values, remaining values, salvage values, and interest rates, as well as the return flow. A nominal cost analysis using nominal interest rates and nominal salvage values for assets, which is then placed in a CAR framework, is an alternative to the use of real interest rates and real salvage values. However, there are a number of limitations to the use of nominal CAR expressions. These limitations include (1) specifying the expected inflation rate and (2) a specified time period for the analysis. This specified time period is necessary so that (a) the nominal cost expressions can be discounted and reamortized to a constant nominal expression and (b) inflation-impacted returns can also be discounted and reamortized to a constant nominal expression. The latter issue is essential to any proper comparison of costs to returns. By removing inflation and using real interest rates, these complexities are reduced significantly.

The use of nominal interest costs and nominal salvage values results in a cost expression (end-of-year) which is constant over the asset's life. This expression can be termed a constant nominal expression with declining real value. For comparability, the corresponding returns also increase nominally over the time period due to inflation. This increasing nominal return flow must be placed on the same constant nominal flow basis as the nominal costing implies. Thus, the increasing nominal return expression must be discounted to a present value and then be amortized at a nominal discount rate for comparability. This requires the explicit use of a finite time period of analysis. In addition, the construction of an increasing nominal return flow requires the assumption of a particular rate of inflation. For these reasons a real CAR budget is preferable to a nominal budget.

A real costing process under inflationary conditions involves the use of real interest rates and a real salvage value and results in the same process as that under no inflation. This process is considerably less complex than the process of forming constant nominal return expressions. It assumes returns in the long run increase with inflation and does not require a specific estimate of inflation. Of course, if there is reason to believe or evidence to suggest a shift in the expected return flows, the real return can be so adjusted.

The Task Force recommends that all CAR estimates have an explicit time point.

The Task Force recommends that CAR estimates use a real interest/discount rate for adjusting CAR flows between years (over time) as when computing opportunity interest cost or capital recovery factors for durable assets.

PROCEDURES FOR COST ESTIMATION

Economic depreciation and opportunity cost can be estimated in two general ways. One is the splitting of the two as an approximation. This procedure can be termed as traditional, and results in

$$D = \frac{V_0 - V_n}{n} = \frac{PP - SV}{n} \qquad \textbf{(6.5)}$$

$$OC = \left(\frac{V_0 + V_n + D}{2}\right)(r) = \left(\frac{PP + SV + D}{2}\right)(r) \qquad \textbf{(6.6)}$$

where

V_0	=	Value of asset at the beginning of period 1 (end of period 0)
V_n	=	Value of asset at the end of period n
D	=	Straight-line economic depreciation occurring during each period
PP	=	Purchase price of asset at beginning of the first period
SV	=	Salvage value of asset at end of period n
OC	=	Opportunity interest cost
r	=	real interest rate
n	=	time period in years.

It is assumed that all values are in real terms. V_0 is generally the purchase price of a new piece of equipment and V_n is almost always estimated based on the list price of new equipment. Equation 6.6 is slightly different from the formula often seen in farm management textbooks and extension publications. In Equation 6.6, depreciation is included in the numerator rather than taking a simple average of purchase and salvage values. This is because the opportunity interest cost is computed on the value of the investment at the beginning of the year because the asset is held for the entire year. For clarification, compare equations 6.5 and 6.6 with a one-year time horizon to equation 2.20 assuming a real interest rate and no inflation. Equation 2.20 gives the opportunity cost at the end of the year of holding the asset for one year. Equation 2.20 with no inflation is

$$\begin{aligned} OC &= V_0\ i \\ &= V_0(\pi + r + \pi r) \\ &= V_0(0 + r + 0r) \\ &= V_0 r \end{aligned} \qquad \textbf{(2.20)}$$

where i is the nominal interest rate, π is the rate of inflation, and r is the real interest rate. Rewriting equations 6.5 and 6.6 assuming a one year time horizon gives

$$\begin{aligned} D &= \frac{V_0 - V_1}{1} \\ &= V_0 - V_1 \end{aligned}$$

$$\begin{aligned} OC &= \left(\frac{V_0 + V_1 + D}{2}\right)(r) \\ &= \left(\frac{V_0 + V_1 + (V_0 - V_n)}{2}\right)(r) \\ &= \left(\frac{2V_0}{2}\right)(r) = V_0 r\,. \end{aligned}$$

Depreciation is removed if a midyear value for the opportunity cost is desired. Including depreciation in the equation makes this method perform more closely to the exact capital recovery (annuity) method discussed later, and corrects for the inherent negative bias present if D is excluded (Walrath; Kay). As the length of each time period decreases, the importance of D also decreases with it disappearing in the limit.

Watts and Helmers (1979) have discussed further the reasons for adding D to equation 6.6 rather than eliminating it to get a midyear asset value. A simple example demonstrates this point. Suppose an asset with zero salvage value costs $100,000 originally and has a life of five years. Straight-line depreciation is $20,000 per year. Opportunity interest cost (per year) is usually perceived to be charged on the beginning-of-year asset value. In this case, the values are $100,000, $80,000, $60,000, $40,000, and $20,000, respectively. Using a 4% real interest rate results in opportunity interest costs of $4,000, $3,200, $2,400, $1,600, and $800, respectively, or a simple average of $2,400. The use of equations 6.5 and 6.6 gives the same result as follows

$$D = \frac{100{,}000}{5} = 20{,}000$$

$$OC = \left(\frac{100{,}000 + 0 + 20{,}000}{2} \right) (.04) = 2{,}400 .$$

Removing D results in an opportunity cost estimate of $2,000 [(100,000/2)(.04)]. This implicitly requires interest charges to be charged on the midyear values of $90,000, $70,000, $50,000, $30,000 and $10,000, or $3,600, $2,800, $2,000, $1,200 and $400, to give the average of $2,000.

The second and exact method (sometimes termed capital recovery or an annuity cost) is the annualizing of the two components (economic depreciation and opportunity cost) together. This method is presented as Equation 6.7. Equation 6.7 is identical to the capital budgeting approach where original cost less the present value of the salvage value is amortized over its life. It is also the same as equation 2.31 where V_n is in real terms and CSC is the capital service cost expressed as an annuity.

$$CSC = \frac{\left(V_0 - \frac{V_n}{(1+r)^n} \right)}{\left(\frac{1 - \frac{1}{(1+r)^n}}{r} \right)} = \frac{\left(PP - \frac{SV}{(1+r)^n} \right)}{\left(\frac{1 - \frac{1}{(1+r)^n}}{r} \right)} . \qquad \textbf{(6.7)}$$

The denominator in equation 6.7 is a uniform series (US_0) with interest rate r and period n as defined in equation 2B.8. Thus, CSC can be computed using the standard annuity functions available on business calculators or in spreadsheet programs (such as PMT in EXCEL). For such canned procedures $\left(V_0 - \frac{V_n}{(1+r)^n} \right)$ is used as the present value of the annuity with the assumption that the payment is made at the end of the period. Equation 6.7 can also be written in an alternative fashion as follows

$$CSC = \frac{(PP - SV)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} + SV(r)$$
$$= \frac{(PP - SV)r}{1 - (1+r)^{-n}} + SV(r)\,. \qquad \textbf{(6.8)}$$

The steps in going from 6.7 to 6.8 are contained in Appendix 6B. The appropriate forms for a nominal annuity are also contained in this appendix. The capital recovery method gives a constant annual payment that has the same present value as the economic cost of holding the asset for n periods computed using the methods discussed in Chapter 2. This method accounts for costs due to service reduction, changes in market price, and the opportunity cost associated with the financial capital tied up in the asset.

These two methods (traditional and capital recovery) typically use a new cost and expected salvage value without concern about the nature of the remaining value function (depreciation) over the asset life. This is because the costing process is only concerned with the average cost over the lifetime of the asset, not individual years. Even if V_0 is for a purchased used asset, once V_n is determined, the analysis assumes straight-line depreciation over the remaining life and an average cost over this period is obtained. The expected salvage value assumes no change in the asset value due to inflation because this is a real analysis. Adjusted formulas using nominal interest rates are discussed in the example below.

The capital recovery approach is well-suited to the inclusion of maintenance and other time costs in the construction of an annual capital service cost, while the traditional method is not. Rather than using $\left(V_0 - \dfrac{V_n}{(1+r)^n}\right)$ (which represents only the discounted value of the change in market value over the asset's life) in the numerator of equation 6.7, the present value of the entire cost/income stream associated with the asset can be used in computing an annual annuity payment associated with the durable asset. An example of this procedure is contained in Appendix 2C.

EXAMPLE COST CALCULATION FOR A DURABLE ASSET

A simple example under no inflation and inflation situations is presented here. It assumes an asset with a purchase price (PP) of $105,000, a useful life (n) of five years at 400 hours per year, and a salvage value (SV) of $5,000 (real or noninflated dollars). It is assumed that maintenance and other time costs are accounted for elsewhere. The total cost per year, as well as per hour, is estimated. This can be further allocated on a per acre or per bushel basis. A higher use of the asset per year (say 500 hours) would reduce its expected life to four years if it is assumed that the asset has 2,000 hours of life. In such a case the interest portion of the ownership cost per hour of use changes.

Costs with No Inflation

Assume a 4% real interest/discount rate. The traditional cost method is computed in two parts as follows

$$D = \frac{PP - SV}{n}$$

$$= \frac{(105{,}000 - 5{,}000)}{5} = 20{,}000$$

(6.9)

$$OC = \left(\frac{PP + SV + D}{2} \right) (r)$$

$$= \left(\frac{105{,}000 + 5{,}000 + 20{,}000}{2} \right) (.04) = 2{,}600 .$$

The traditional method thus results in a cost of $20,000 per year or $50 per hour for economic depreciation and $2,600 per year or $6.50 per hour for opportunity cost, for a total annual cost of $22,600 ($56.50 per hour). The capital recovery cost is computed using equation 6.7 as follows

$$CSC = \frac{\left(PP - \frac{SV}{(1+r)^n} \right)}{\left(\frac{1 - \frac{1}{(1+r)^n}}{r} \right)}$$

$$= \frac{\left(105{,}000 - \frac{5{,}000}{(1.04)^5} \right)}{\left(\frac{1 - \frac{1}{(1.04)^5}}{.04} \right)}$$

(6.10)

$$= \frac{105{,}000 - \frac{5{,}000}{1.21665}}{4.451822}$$

$$= \frac{105{,}000 - 4{,}109.6355}{4.451822}$$

$$= \frac{100{,}890.364}{4.451822}$$

$$= 22{,}662.711 .$$

The annual cost using this method is thus $22,662.71 ($56.66 per hour). Both are end-of-year estimates. A return flow of $22,662.71 per year (received at end of each year) would then exactly exhaust the initial cost of the machine.

Inflation

If we assume a 4% real interest rate, the same as for the no inflation scenario, and a 5% inflation rate, the implied nominal rate is 9.2%. One way to introduce inflation is to adjust the real values computed in equation 6.10. The real cost estimate is $22,662.71 or $56.66 per hour as before. A real annual return of $22,662.71 would exactly exhaust the machine cost. The value of this cost stream at the end of the first year is $23,795.85 [($22,662.71)(1.05)]. The equivalent nominal values at the end of years two to five are $24,985.64, $26,234.92, $27,546.67, and $28,924 respectively, where each return rises at the rate of inflation. If the CAR analysis for a single year is done in nominal terms at the end of the year as suggested by this Task Force, then the appropriate annual cost for this asset is $23,795.85 (the end of first year value). As mentioned in Chapter 2, the Task Force recommends that analysis for years other than the current one be done in real terms. This implies that the price of the machine increases by 5% during the first year, but remains at this real value for future years. Similar assumptions must be made about each asset and return stream included in the CAR estimate.

An alternative approach to introduce inflation is to make the computation in nominal terms using nominal interest rates and nominal salvage values. With 5% inflation per year the projected salvage value is $6,381.41 [(5,000)(1.05)^5]. For the traditional method, the nominal costs are given by

$$D = \frac{(105{,}000 \; - \; 6{,}381.41)}{5} = 19{,}723.72$$

$$OC = \left(\frac{105{,}000 \; + \; 6{,}381.41 \; + \; 19{,}723.72}{2} \right) (.092) = 6{,}030.84 \qquad \textbf{(6.11)}$$

which gives total nominal costs of $25,754.56 ($64.39 per hour). The capital recovery (annuity) method is computed using the nominal version of equation 6.7, a nominal interest rate of 9.2%, and the nominal salvage value as follows

$$CSC = \frac{\left(105{,}000 \; - \; \dfrac{6{,}381.408}{(1.092)^5} \right)}{\left(\dfrac{1 \; - \; \dfrac{1}{(1.092)^5}}{.092} \right)} \qquad \textbf{(6.12)}$$

$$= \frac{100{,}890.364}{3.86955}$$

$$= 26{,}072.89 \, .$$

Making the computations in nominal values results in a cost of $26,072.89 which is equivalent to $65.18 per hour in constant nominal dollars. The problem with using this cost as opposed to the $23,795.84 computed previously is that this nominal annuity assumes that inflation will continue at 5% over the life of the asset. A similar assumption would need to be made for other assets, each with its own useful life and potentially different inflation values, as well as for future returns. Thus the real annuity adjusted to the end of the year using the annual inflation rate resulting in a cost of $23,795.84 is the preferred method.

The inflated real and nominal streams have the same present value. This can be seen by computing the value of each stream at the end of the first year assuming a nominal interest rate of 9.2%. This gives

$$\begin{aligned} V_1^r &= 23{,}795.85 + \frac{24{,}985.64}{(1.092)} + \frac{26{,}234.92}{(1.092)^2} + \frac{27{,}546.67}{(1.092)^3} + \frac{28{,}924}{(1.092)^4} \\ &= 11{,}0172.28 \\ V_1^n &= 26{,}072.89 + \frac{26{,}072.89}{(1.092)} + \frac{26{,}072.89}{(1.092)^2} + \frac{26{,}072.89}{(1.092)^3} + \frac{26{,}072.89}{(1.092)^4} \\ &= 11{,}0172.28 \end{aligned} \tag{6.13}$$

where V_1^r and V_1^n denote the value at the end of period one of the inflated real and constant nominal streams, respectively.

A table similar to Table 2.12 for this example is presented in Table 6.5 for easy reference and comparison. This table uses equation 2.28 to compute the capital service cost as the sum of the opportunity cost and the combined cost of service reduction and the changes in price. The equation is repeated here for convenience. The table also divides up opportunity interest into inflation and real interest components following the procedures in Appendix 2A.

$$\begin{aligned} \textit{Capital service cost } (CSC) &\approx \textit{Opportunity cost} + \textit{service reduction cost} + \textit{change in price} \\ &= \textit{Opportunity cost} + (V_0 - V_1) \\ &= iV_0 + (V_0 - V_1)\,. \end{aligned} \tag{2.28}$$

Annual straight-line depreciation in real terms is $20,000 per year. With inflation, this gives a nominal stream equal to [21,000, 22,050, 23,152.5, 24,310.125, 25,525.631]. The ending (salvage) value of the asset in nominal terms is $6,381.41. Notice that the opportunity cost (reported in the investment row) falls over time from $9,660 to $2,795.66 while the costs due to changes in value rise from $15,750 to $24,006.25 due to increases in the price level. This last category would be constant at $20,000 if there were no inflation.

If one were to assume that depreciation followed a sum-of-the-years pattern for five years the depreciation factors would be (.3333, .2667, .20, .1333, .0667) with annual real depreciation of $33,333, $26,667, $20,000, $13,333, and $6,667. Table 6.6 presents the same information as Table 6.5 but for this case. Notice that present value of total costs and the real and nominal annuities do not change. Thus the choice of straight-line or sum-of-the-years for depreciation in use value has no impact on the cost analysis. It will, however, affect the estimated market value of the asset during the period the asset is held. The lower charges for opportunity interest costs in early years are compensated for by higher charges for service reduction and changes in price.

If an asset is used more heavily during a given year so that its useful life (in years) is less, the costs of ownership and use will change. For the above example, with 500 hours of use per year, the asset life is only four years. This would result in an annual real cost of $27,749.00 ($55.50 per hour) using the capital recovery method and an annual real cost of $27,700 ($55.40 per hour) for the traditional method. Similarly, using a nominal analysis the capital recovery cost per year is $31,227.55 ($62.46 per hour) whereas the traditional method results in an annual cost of $30,977.79 ($61.96 per hour). It is well recognized that age and actual obsolescence impact the cost of depreciable assets. However, in CAR estimates, developing depreciation and interest costs on a per hour of use basis using expected annual use and expected obsolescence is the preferred approach.

A nominal analysis becomes impractical in most CAR estimates because of the various asset lives of durables in firms. A consistent nominal analysis involving a changing dollar value requires the return side to have the same time period of analysis as the cost side. Yet farms have durables with various asset lives. This is complicated further by land ownership because land is an infinitely lived asset. Thus, a proper nominal analysis would require enormous capital budgeting adjustments to reach meaningful CAR expressions.

The Task Force recommends the capital recovery (annuity) method of calculating annual depreciation and interest costs over the traditional method.

The Task Force recommends that the capital recovery method of calculating annual depreciation and interest costs use a real interest rate for computation and then inflate this cost to the end of the first year using the annual rate of inflation.

The Task Force recommends that because annual asset use affects the replacement interval and therefore depreciation and opportunity interest costs, these costs should be constructed on a per hour of use basis for inclusion in cost and return estimates.

Given that some decline in use value may occur due to time and obsolescence in addition to machine use, the Task Force recommends that careful consideration be given in choosing the useful life of equipment and machinery so that older machines with low hours of use do not have their use value overstated.

Other Costs

Normally, estimates of property taxes and insurance are based on tax and insurance rates multiplied by the asset midvalue. For economic costing only an average value over the asset's lifetime is of interest. This is given by an average of the initial and salvage values. Insurance rates and property tax rates vary by state and by asset type. Appropriate housing may not increase an asset’s life but it may increase its salvage value (Hunt, 1995: 71). Data on housing costs like that on taxes and insurance vary widely from farm to farm and state to state. When data are not available, the ASAE (ASAE EP496.2 MAR94 in ASAE [1997]) recommends percentages of the purchase price of the asset as presented in Table 6.7. When a purchase price is not available, a list price or some percentage of it may be used as a proxy. These costs are then added to the other annual costs of use for the durable asset.

JOINT COSTS AND OPTIMAL INPUT COMPLEMENTS

As mentioned in the introduction to this chapter, multiple enterprise use of durable inputs is common in agriculture. Most farms produce more than one product. When this occurs, durable factors of production as well as other inputs may be shared among enterprises. In some situations, two enterprises may share the use of a particular durable input, while other enterprises on the farm may not. This would be the case for a farm where the crop enterprises use all the tractors and crop land, while the livestock enterprises only use some of the tractors and a small proportion of the land.

The issue of joint costs and joint returns and their allocation in multiple product farms/firms has been long known to involve major conceptual problems. This can also extend to single product farms/firms in which it is desired to assign joint costs to alternative production methods or different forms of production. The theoretical severity of problems in decision making resulting from the arbitrary allocation of joint costs to the respective joint-use outputs is unknown particularly when one CAR statement is used to reflect enterprise cost on different sized farms, and varying output mixes for a given farm size. The result is that under joint-use conditions, when costs of shared durable inputs and labor are arbitrarily assigned to individual enterprises, it is not clear that this is a close approximation to the true input costs attributable to each enterprise. This topic is discussed in more detail in Chapter 9: Joint Costs, General Farm Overhead, and Rights to Produce. Thus in making an allocation of costs to enterprises great care should be taken.

For any static output mix there is an optimal set of durable factors of production. The determination of that set for a particular output system can be secured from farm records or a similar collection of historical data, or in the case of projected CAR estimates a solution can be obtained from engineering estimates, linear programming, capital budgeting techniques, machine optimization programs, and so forth. Useful references on the optimal choice of capital equipment include Reid and Bradford; Perry et al.; Robison and Barry (1996: Chapter 15); Perry and Nixon; Weersink and Stauber; Leatham and Baker; and Bowers (1994). If the purpose of the CAR measurement is enterprise decision making given a specific set of fixed factors, then allocation of these costs across enterprises should be discouraged. If the analysis is long run in nature, then allocation of these costs to a particular output is important. Similarly, if the purpose of the CAR measurement is policy analysis requiring an estimate of the total costs of production, assignment of joint costs is required. In such cases, the intensity of use of any durable input by a product would appear to be the assignment mechanism. For example, the cost of a tractor used by various crop enterprises should not have its cost apportioned by simple hours of use, but the load requirements should be factored in as well.

The Task Force recommends that where CAR estimates are developed for purposes of comparing the profitability of enterprises, costs of fixed assets common to two or more of these enterprises remain unallocated except when required for a specific purpose.

TABLE 6.5 Annual Costs of Using Asset ($105,000 Purchase Price) over a 5-year Period Assuming Equal Annual Depreciation

Annual real interest	4%
Annual inflation rate	5%
Annual nominal interest	9.2%
Original value of asset	$105,000
Depreciation over 5-year time period	$100,000
Salvage value of asset	$5,000
Life in years	5
Annual straight-line depreciation in $	$20,000
Annual use in hours	400
Ending Value $(1+\pi)V_0$ - D	

Capital service cost (CSC) $\approx iV_0 + (V_0 - V_1)$

	Total	**Per Hour**
Nominal Annuity for Capital Service Cost (CSC N)	26,072.893	65.182232
Real Annuity for Capital Service Cost (CSC R)	22,662.711	56.656778

Year	Item	Beginning Value	Opportunity Cost	Inflation Cost	Real Interest Cost	Real Depr.	Nominal Depr.	Ending Value	Total Cost
1	Investment Cost (iV_0)	105,000	9,660	5,250	4,410	20,000	21,000	89,250	9,660
	Service reduction + Change in price (V_0 - V_1)								15,750
	Total Annual Cost (CSC)								25,410
	CSC N								26,072.893
	CSC R with inflation adjustment								23,795.847
2	Investment Cost (iV_0)	89,250	8,211	4,462.5	3,748.5	20,000	22,050	71,662.5	8,211
	Service reduction + Change in price (V_0 - V_1)								17,587.5
	Total Annual Cost (CSC)								25,798.5
	CSC N								26,072.893
	CSC R with inflation adjustment								24,985.639

TABLE 6.5 (continued)

Year	Item	Beginning Value	Opportunity Cost	Inflation Cost	Real Interest Cost	Real Depr.	Nominal Depr.	Ending Value	Total Cost

3	Investment Cost (iV_0)	71,662.5	6,592.95	3,583.125	3,009.825	20,000	23,152.5	52,093.125	6,592.95
	Service reduction + Change in price (V_0 - V_1)								19,569.375
	Total Annual Cost (CSC)								26,162.325
	CSC N								26,072.893
	CSC R with inflation adjustment								26,234.921
4	Investment Cost (iV_0)	52,093.125	4,792.5675	2,604.656	2,187.9113	20,000	24,310.125	30,387.656	4,792.5675
	Service reduction + Change in price (V_0 - V_1)								21,705.469
	Total Annual Cost (CSC)								26,498.036
	CSC N								26,072.893
	CSC R with inflation adjustment								27,546.667
5	Investment Cost (iV_0)	30,387.656	2,795.6644	1,519.382	1,276.2816	20,000	25,525.631	6,381.4078	2,795.6644
	Service reduction + Change in price (V_0 - V_1)								24,006.248
	Total Annual Cost (CSC)								26,801.913
	CSC N								26,072.893
	CSC R with inflation adjustment								28,924.001
	Total cost over entire period								130,670.77
	Average cost								26,134.155
	US_0(.04, 5)	4.4518223							
	US_0(.092, 5)	3.8695501							
	P.V. of annual costs at end of period 1								110,172.28
	P.V. of annual costs at beginning of period 1								100,890.36
	P.V. of nominal annuity (CSC N) at end of period 1								110,172.28
	P.V. of inflating real annuity (CSC R) at end of period 1								110,172.28

TABLE 6.6 Annual Costs of Using Asset ($105,000 Purchase Price) over a 5-year Period Assuming Sum-of-the-years Depreciation

			Year	Depreciation
Annual real interest	4%			
Annual inflation rate	5%		1	33,333.33
Annual nominal interest	9.2%		2	28,666.66
Original value of asset	$105,000		3	20,000
Depreciation over 5-year time period	$100,000		4	13,333.33
Salvage value of asset	$5,000		5	466.66
Life in years	5			
Annual use in hours	400			
Ending Value $(1+\pi)V_0$ - D				
Capital service cost (CSC) $\approx iV_0 + (V_0 - V_1)$				
	Total	**Per Hour**		
Nominal Capital Service Cost (CSC N)	26,072.893	65.182232		
Real Capital Service Cost (CSC R)	22,662.711	56.656778		

Year	Item	Beginning Value	Opportunity Cost	Inflation Cost	Real Interest Cost	Real Depr.	Nominal Depr.	Ending Value	Total Cost
1	Investment Cost (iV_0)	105,000	9,660	5,250	4,410	33,333.33	35,000	75,250	9,660
	Service reduction + Change in price (V_0 - V_1)								29,750
	Total Annual Cost (CSC)								39,410
	CSC N								26,072.893
	CSC R with inflation adjustment								23,795.847
2	Investment Cost (iV_0)	752,500	6,923	3,762.5	3,160.5	26,666.66	29,400	49,612.5	6,923
	Service reduction + Change in price (V_0 - V_1)								25,637.5
	Total Annual Cost (CSC)								32,560.5
	CSC N								26,072.893
	CSC R with inflation adjustment								24,985.639

TABLE 6.6 (continued)

Year	Item	Beginning Value	Opportunity Cost	Inflation Cost	Real Interest Cost	Real Depr.	Nominal Depr.	Ending Value	Total Cost
3	Investment Cost (iV_0)	49,612.55	4,564.35	2,480.63	2,083.725	20,000	23,152.5	28,940.63	4,564.35
	Service reduction + Change in price (V_0 - V_1)								20,671.875
	Total Annual Cost (CSC)								25,236.225
	CSC N								26,072.893
	CSC R with inflation adjustment								26,234.921
4	Investment Cost (iV_0)	28,940.625	2,662.54	1,447.03	1,215.506	13,333.33	16,206.75	14,180.91	2,662.5375
	Service reduction + Change in price (V_0 - V_1)								14,759.719
	Total Annual Cost (CSC)								17,442.256
	CSC N								26,072.893
	CSC R with inflation adjustment								27,546.667
5	Investment Cost (iV_0)	14,180.906	1,304.64	709.045	595.598	666.666	8,508.5438	6,381.4078	1,304.6434
	Service reduction + Change in price (V_0 - V_1)								7,799.4984
	Total Annual Cost (CSC)								9,104.1481
	CSC N								26,072.893
	CSC R with inflation adjustment								28,924.001
	Total cost over entire period								123,733.23
	Average cost								24,746.624
	US_0 (.04, 5)	4.4518223							
	US_0 (.092, 5)	3.8695501							
	P.V. of annual costs at end of period 1								110,172.28
	P.V. of annual costs at beginning of period 1								100,890.36
	P.V. of nominal annuity (CSC N) at end of period 1								110,172.28
	P.V. of inflating real annuity (CSC R) at end of period 1								110,172.28

TABLE 6.7 Annual Costs of Taxes, Housing, and Insurance as a Percentage of Purchase Price

Annual Cost Item	% of Purchase Price
Taxes	1.00
Housing	.75
Insurance	.25
Total	2.00

APPENDIX 6A

Combining Ownership and Use Costs for Durable Assets with Variable Productivity

As discussed in the section of Chapter 2 entitled Defining Factors of Production and Products, cost of production studies typically assume constant productivity across time for most inputs including machinery, equipment, and buildings. The justification for constant productivity of machinery is that appropriate and increasing repair expenditures can maintain service capacity at an undiminished rate. The assumption of variable productivity is often more reasonable in the case of breeding livestock, perennial crops, some types of wells, and some land or range resources. Furthermore, it may also be appropriate to compute machinery costs assuming a variable rate of productivity over time. This appendix considers a method called the unit cost theory of depreciation originally developed by J. S. Taylor and refined by Harold Hotelling which computes a cost of ownership *and use* based not on units of the asset but on units of output produced by the asset[1]. By considering the output produced by an asset of age t, the cost measure computed implicitly accounts for differences in productivity over time. A more complete discussion of this approach is contained in Burt (1992).

The approach assumes time to be discrete and that the economic life for the asset is known (as opposed to random). All monetary values are implicitly defined with respect to the purchasing power of money at a single point in time, i.e., adjusted for inflation when measured over time. All interest rates are then assumed to be real. Consider an asset with acquisition cost or purchase price at the beginning of year one of V_0 and a net salvage value at the end of year n of V_n. The output produced using this asset in year t of its of life is denoted Q_t. For an orchard this might be the bushels of peaches produced which varies over the life of the orchard. For a dairy cow it might be milk production per year which will fall in the later years of the cows life. Similarly with a stand of alfalfa. For a tractor the output might be quality adjusted hours of service potential. For example, a five-year-old tractor that has been used 200 hours per year (1,000 total hours) may have a different service capacity than a 20-year-old tractor that has been used 50 hours per year. The idea behind valuing the remaining service differently is that an hour produced by an old machine might be of less value than an hour produced by a newer machine due to more likely frequency of breakdown by the older machine. Let the annual operating and maintenance outlays (including labor) associated with the asset be denoted C_t. These, as well as output, are assumed to occur at the end of the year for simplicity. The implicit rent on the asset in period t is given by

$$implicit\ rent = uQ_t - C_t \tag{6A.1}$$

where u is defined as the nonnegative unit cost for the service flow Q_t. For a given replacement age n, the present value of rents plus net salvage value set equal to purchase price V_0, i.e., unit cost is implicitly determined by

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[1]The unit cost measure defined here was called "unit cost plus" by Taylor to distinguish it from a simple measure that ignored interest costs, but later writers called it simply "unit cost." Hotelling used the term "theoretical selling price" for what is here called unit cost.

$$V_0 = \sum_{t=1}^{n} \beta^t (uQ_t - C_t) + \beta^n V_n \qquad \textbf{(6A.2)}$$

where $\beta = \frac{1}{1+r}$ and r is the real interest rate. Solving 6A.2 for u gives

$$u = \frac{[(V_0 - \beta^n V_n) + \sum_{t=1}^{n} \beta^t C_t]}{[\sum_{t=1}^{n} \beta^t Q_t]} . \qquad \textbf{(6A.3)}$$

Unit cost is quite intuitive economically; it is the present value of all costs minus the present value of salvage, all divided by a weighted sum of output over the life of the asset where the weight at age t is the present value weight β^t (discounted value of total output measured in physical units).

After incurring the initial investment cost (V_0), the present value of the remaining services in the asset at the end of period t would be

$$V_t = \sum_{j=t+1}^{n} \beta^{j-t} (uQ_j - C_j) + \beta^{n-t} V_n \qquad \textbf{(6A.4)}$$

for t = 0, 1,...n. Note that V_0 defined by 6A.4 is simply the right-hand side of (6A.2). The annual economic depreciation (ED_t) charges are given by

$$ED_t = V_{t-1} - V_t . \qquad \textbf{(6A.5)}$$

These charges will sum to V_0 - V_n and so are what is called accounting admissible. The summation of ED_t in (6A.5) from t=1 to t=n yields canceling terms in V_t, t = 1,2,...n-1, which leaves V_0 - V_n. The unit cost u is then a charge per unit of output that can be incorporated in cost of production estimates. It is a constant per unit charge that reflects the full cost of owning and operating the asset over its useful life. It accounts for differences in the output and operating costs associated with the asset at different times in its productive life with full recognition given to the time distribution of the services and costs.

The estimation of unit cost is simplified considerably when output Q_t is constant over age of the asset because uQ_t reduces to a constant over time. Denote this constant by $u\bar{Q} = a^r$. If we substitute for uQ_t in 6A.2 we can derive a constant annual charge,

$$a^r = \frac{[(V_0 - \beta^n V_n) + \sum_{t=1}^{n} \beta^t C_t]}{[\sum_{t=1}^{n} \beta^t]} \qquad \textbf{(6A.6)}$$

To better interpret 6A.6 rewrite the denominator as

$$\sum_{t=1}^{n} \beta^t = (\frac{1}{1+r} + \frac{1}{(1+r)^2} + \cdots + \frac{1}{(1+r)^n}) = US_0(r,n) \qquad \textbf{(6A.7)}$$

following equation 2B.7. Rewriting 6A.6 by using the alternative definition of US_0(r,n) from equation 2B.8 and writing $\left[\frac{1}{1+r}\right]^t$ for β^t we obtain

$$a^r = \frac{\left[\left(V_0 - \frac{V_n}{(1+r)^n}\right) + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}\right]}{US_0(r,\ n)}$$

$$= \frac{\left[\left(V_0 - \frac{V_n}{(1+r)^n}\right) + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}\right]}{\left(\frac{1 - \frac{1}{(1+r)^n}}{r}\right)} \qquad \textbf{(6A.8)}$$

which is the real version of equation 2C.3 assuming no operating or maintenance costs at time zero. Thus when output is a constant over time u reduces to

$$u = \frac{a^r}{\bar{Q}}. \qquad \textbf{(6A.9)}$$

This is the same as the common approach used to derive a cost per unit of service where the annual charge is divided by the hours of use or units of output to get a cost per unit of service. For machinery this would imply dividing the cost per year by the number of hours of use to get a cost per hour.

Economic depreciation is still given by (6A.5). The present value of the asset at the end of year t from equation 6A.4 can be written in this case by substituting a^r for uQ_j as follows

$$V_t = \sum_{j=t+1}^{n} \beta^{j-t}(a^r - C_j) + \beta^{n-t}V_n . \qquad \textbf{(6A.10)}$$

The difference in the computation of u using 6A.3 and as opposed to 6A.8 and 6A.9 makes it clear that in the general case of (6A.3), one cannot simply calculate unit cost by a proportional adjustment to annual cost of owning the asset as in 6A.9.

In (6A.8) a^r is a real annuity representing the amortized present value of the costs of owning and operating the asset, but in (6A.3) the unit cost of service from the asset depends on the sum of the product of the discount factor and the amount of services from the asset each year throughout the future life of the asset, not just the discount factor alone. Consequently, the cost of a specific number of units of service from an asset cannot be calculated from the amortized present value of costs associated with ownership of the asset unless the quantity of services is constant during each period in the life of the asset; the distribution of services from the asset over its life is an intrinsic part of the weighting required to calculate unit cost of the services. It is intuitively clear from (6A.3) that a relatively large number of services provided early in the life of the asset relative to later in its life will tend to reduce unit costs and vice versa. This may be particularly important for machinery assets where timeliness and absence of breakdowns is essential for efficient planting and harvesting of crops during small windows of favorable weather. In such situations, additional repair expenditures may not compensate for poorer performance by an older machine. In such cases, the separation of operating costs (maintenance and repairs) from ownership costs as suggested by this report may be inappropriate and the more complicated formula in equation 6A.3 should be considered. This may be particularly relevant for assets such as perennial crops or breeding livestock where productivity is clearly changing over the lifetime of the asset. For a further discussion see the Appendix 10B.

APPENDIX 6B

Alternative Forms of the Equation for a Real and Nominal Annuity for Calculating Capital Costs

The preferred method to compute economic depreciation and opportunity cost for a capital asset is to calculate the real or nominal annuity that has the same net present value as the stream of cash flows associated with holding the asset for a number of periods. This is presented in the text as equation 6.7. Equation 6.7 is identical to capital budgeting where original cost less the present value of the salvage value of the asset is amortized over its life. Equation 6.7 is the same as equation 2.31 where V_n is in real terms and CSC is the capital service cost expressed as an annuity. The real version of equation 6.7 can also be written in an alternative fashion as in equation 6.8. The steps in going from 6.7 to 6.8 are as follows

$$\begin{aligned}
CSC &= \frac{\left(PP - \dfrac{SV}{(1+r)^n}\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} \\
&= \frac{\left(PP - \dfrac{SV}{(1+r)^n} - SV + SV\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} \\
&= \frac{\left(PP - SV + SV\left(1 - \dfrac{1}{(1+r)^n}\right)\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} \qquad \textbf{(6B.1)} \\
&= \frac{(PP - SV)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} + \frac{SV\left(1 - \dfrac{1}{(1+r)^n}\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} \\
&= \frac{(PP - SV)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^n}}{r}\right)} + (SV)\,(r)\,.
\end{aligned}$$

A nominal form of equation 6.8 (6B.1) can also be developed. In this case the salvage value must be in nominal dollars. The real value at time 0 is multiplied by $(1+\pi)^n$ to adjust it forward n periods. The nominal version of 6.7 is then given by

$$CSC = \frac{\left(PP - \frac{SV(1+\pi)^n}{(1+i)^n}\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)} . \qquad \textbf{(6B.2)}$$

This can be modified to give an equation similar to 6.8 as follows

$$CSC = \frac{\left(PP - \frac{SV(1+\pi)^n}{(1+i)^n}\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)}$$

$$= \frac{\left(PP - \frac{SV(1+\pi)^n}{(1+i)^n} - SV(1+\pi)^n + SV(1+\pi)^n\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)}$$

$$= \frac{\left(PP - SV(1+\pi)^n + SV(1+\pi)^n\left(1 - \frac{1}{(1+i)^n}\right)\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)} \qquad \textbf{(6B.3)}$$

$$= \frac{\left(PP - SV(1+\pi)^n\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)} + \frac{SV(1+\pi)^n\left(1 - \frac{1}{(1+i)^n}\right)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)}$$

$$= \frac{(PP - SV(1+\pi)^n)}{\left(\frac{1 - \frac{1}{(1+i)^n}}{i}\right)} + SV(1+\pi)^n(i) .$$