CHAPTER 12 – Depreciation Methods

Lecture 29 Depreciation Basics

Corporations, like individuals, have to pay income taxes on their annual *earnings*. Earnings is just another name for *profits* which is the difference between revenues and expenses:

Profits = Revenues – Expenses

Expenses include all of the costs incurred in generating that revenue, including wages, raw materials, overhead, and capital spending on things like equipment. Most of these costs (and the revenue they make possible) are incurred throughout the life of the project. But capital costs are typically incurred just once, at the start of the project.

While it would be tempting to treat capital spending as a Year 0 expense, companies are not allowed to deduct the entire cost of capital equipment all at once because the equipment will be used for many years to generate revenue. Instead, only a portion of the capital spending can be used to offset the company's revenue in any given year. That portion is called the *depreciation*.

The goal is to depreciate the entire cost of the capital equipment by the end of the project life. Companies keep up with how much of the cost they have already depreciated through something called the **book value** of the asset.

The **book value (BV)** is equal to the initial delivered and installed cost of the asset, which is referred to as either the **first cost (P)** or the **basis (B)**, minus the amount that has already been written off (depreciated) on the company's taxes. Put another way, the book value is the portion of the first cost that has yet to be written off on the company's taxes.

At the end of every year, the book value of the asset is updated by subtracting that year's depreciation amount from the previous year's book value:

$$\mathsf{BV}_t = \mathsf{BV}_{t-1} - \mathsf{D}_t$$

Depreciation is simply a bookkeeping device. It doesn't represent any sort of cash flow because no money changes hands. It also doesn't represent the actual loss in value of the equipment over time (which is determined in the marketplace). In fact, at any point in time, a piece of equipment has both a **book value** and a **market value**.

The **market value (MV)** is the amount the asset could be sold for on the open market. It captures the true change in value of the asset over time. What we've been calling the **salvage value (S)** is just the market value of the asset at the end of the study period (*n*). But capital equipment has a market value at every point in time, not just at the end of the study period.

Numerous methods have been used over the year to calculate the annual depreciation amount. We will look at two in particular: straight-line depreciation and declining-balance depreciation. Then we'll look at MACRS depreciation, which combines features of those two methods.

Straight-Line Depreciation

The straight-line method writes off the cost of an asset uniformly over a given **recovery period**. The recovery period (n) is just the length of time over which you're going to use depreciation to reduce your taxes. Uniform depreciation means you're writing off the same amount every year until you've **recovered** the entire cost of the asset.

The name "straight-line method" comes from the fact that a plot of book value over time is just a straight line under this method.



If an asset has a basis B and a salvage value S and will be written off over n years, then the annual depreciation amount is just

$$D_t = \frac{B-S}{n}$$

The book value of the asset at any time *t* can be calculated recursively:

$$\mathsf{BV}_t = \mathsf{BV}_{t-1} - \mathsf{D}_t$$

or, since D_t is a constant, it can be calculated directly from the first cost as

$$BV_t = B - t D_t$$

Let's look at the Ferryman Example from earlier this semester:

Ferryman Example 2

In 2004, Ferryman Company, a titanium producer in Pennsylvania, expanded its operations with the purchase of a \$10 million rolling mill. Assume the new mill was fired up at the start of 2005 and runs at its peak capacity of 4 million pounds of output per year for 10 years. Assume that each pound of output generates \$9.00 in revenues while costing \$4.00 to produce. Assume that O&M costs are \$10 million in 2005 and grow by \$1 million per year after that. At the end of 10 years the mill will be sold for scrap for \$500,000. Calculate the annual depreciation on the rolling mill using straight-line depreciation. What is the book value at the end of 2007?

The problem statement says the mill was "fired up" at the start of 2005. Another way to say this is the mill was **put into service** in 2005. You can't start to depreciate an asset until you put it into service because you don't start generating revenue until you put it into service. So the recovery period begins in 2005.

In 2005, Ferryman's revenue will be (4 million)(\$9 - \$4) = \$20,000,000 and their operating and maintenance expenses will be \$10,000,000 so their earnings are

Earnings (profit) =
$$$20,000,000 - $10,000,000 = $10,000,000$$

At the end of the year, when it comes time to pay income taxes on these earnings, they can reduce what they owe by writing off part of the cost of the rolling mill. The amount they can write off using straight-line depreciation is

$$D_{t} = \frac{B-S}{n} = \frac{\$10,000,000 - \$500,000}{10} = \$950,000$$

So they only have to pay taxes on 10,000,000 - 950,000 = 9,050,000. This reduces their tax bill by 950,000 / 10,000,000 = 9.5%. It also lowers the book value of the rolling mill by 950,000:

$$BV_{2005} = B - D_t = \$10,000,000 - \$950,000 = \$9,050,000$$

At the end of 2006, they can write off another \$950,000 on their taxes, lowering the book value of the mill to

$$BV_{2006} = BV_{2005} - D_t = \$9,050,000 - \$950,000 = \$8,100,000$$

At the end of 2007, they can write off another \$950,000 on their taxes, lowering the book value of the mill to

The book value at the end of 2007 (which is Year 3 of the recovery period) could also have been calculated directly from the first cost as

$$BV_{2007} = B - 3 D_t = $10,000,000 - 3 \times $950,000 = $7,150,000$$

Note that at the end of 2014 (Year 10 of the recovery period) the book value will be

$$BV_{2014} = B - 10 D_t = \$10,000,000 - 10 \times \$950,000 = \$500,000$$

which is, of course, the assumed salvage value of the rolling mill. At that point, Ferryman has depreciated everything that it can on this rolling mill. They can't depreciate the salvage value because that represents \$500,000 in additional revenue that year, not an expense.

Declining-Balance Depreciation

Instead of writing off a fixed amount each year, the declining-balance method writes off a fixed percentage of the remaining book value each year:

$$D_t = d \cdot BV_{t-1}$$

Note that the **depreciation rate** (d) doesn't change over time, but the **depreciation amount** (D_t) does. It's relatively large in the early years and gets smaller toward the end of the recovery period. This allows the company to recover its capital costs more quickly than it would using straight-line depreciation.

Why would a company want to do this? Remember, the company wants to recover its initial investment in as few years as possible. A reduction in taxes is the same as putting money in your pocket; the tax savings effectively increase the company's annual revenue and therefore can reduce the payback period for the project.

Under declining-balance depreciation, the book value at any point in time can be calculated recursively as

$$BV_{t} = BV_{t-1} - D_{t} = BV_{t-1} - d \cdot BV_{t-1} = (1 - d) BV_{t-1}$$

Note that $BV_{t-1} = (1 - d) BV_{t-2}$ so we can also write this as

$$\mathsf{BV}_{t} = (1-d)\mathsf{BV}_{t-1} = (1-d)(1-d)\mathsf{BV}_{t-2} = (1-d)^2 \mathsf{BV}_{t-2}$$

Since $BV_{t-2} = (1 - d) BV_{t-3}$ we can also write this as

$$BV_{t} = \left(1 - d\right)^{2} BV_{t-2} = \left(1 - d\right)^{2} \left(1 - d\right) BV_{t-3} = \left(1 - d\right)^{3} BV_{t-3}$$

This calculation can be continued all the way back to BV_0 which is the original basis, B. So the book value at the end of any year can be calculated directly from the basis as

$$\mathsf{BV}_{\mathsf{t}} = (\mathbf{1} - \mathsf{d})^{\mathsf{t}} \mathsf{B}$$

Using this equation, we can calculate the book value at the end of the recovery period as

$$\mathsf{BV}_{\mathsf{n}} = (1-\mathsf{d})^{\mathsf{n}} \mathsf{B}$$

Note that this **implied salvage value** is <u>not</u> equal to the actual salvage value. It may be more or it may be less, depending on the value of *d*, but the actual salvage value doesn't appear in any of the calculations; it isn't taken into account in this method. Instead, if the company sells the mill for **more** than the final book value, the difference is treated as a capital gain (and they pay taxes on the extra revenue); if they sell the mill for **less** than the final book value, the difference is treated as a capital book value, the difference is treated as a capital loss (which means they get to deduct that amount from their earnings).

The depreciation rate is calculated as a fixed percentage of the previous year's book value:

$$\mathsf{d} = \left(\alpha\right) \frac{100\%}{n}$$

The most common form of declining-balance depreciation is **double-declining-balance** depreciation where $\alpha = 2$. Other common multipliers are 1.5 and 1.25.

A multiplier of 1 provides the same depreciation during Year 1 as straight-line deprecation (if we ignore the salvage value), so a multiplier of 2 for double-declining-balance depreciation means you write off double the amount in Year 1 as you could using straight-line depreciation, thus the name "double" declining balance.

The figure below shows the book value over time for the Ferryman problem under straight-line depreciation and three different levels of declining balance depreciation:



Notice that, as α increases, you get to depreciate more in the early years and less in the later years. That's why it is called an *accelerated depreciation method*. Note, too, that the smaller α is, the greater the implied salvage value.

Let's see how the curve above for $\alpha = 2$ (double-declining-balance) was calculated. The curves for the other values will follow the same approach.

Ferryman Example 3

In 2004, Ferryman Company, a titanium producer in Pennsylvania, expanded its operations with the purchase of a \$10 million rolling mill. Assume the new mill was fired up at the start of 2005 and runs at its peak capacity of 4 million pounds of output per year for 10 years. Assume that each pound of output generates \$9.00 in revenues while costing \$4.00 to produce. Assume that O&M costs are \$10 million in 2005 and grow by \$1 million per year after that. At the end of 10 years the mill will be sold for scrap for \$500,000. Calculate the book value at the end of 2007 and the depreciation amount for 2008 using double-declining balance depreciation.

Assuming a 10-year recovery period, the amount we'll write off at the end of each year is

$$d = \left(2\right) \frac{100\%}{10} = 20\%$$

of the book value at the start of the year.

Let's first step through this one year at a time to show how it works, then we'll take a shortcut and calculate the book value directly from the first cost. Keep in mind that the rolling mill was put into service in 2005, so that is the first year that Ferryman can use depreciation to reduce their taxes.

At the end of 2005, the amount they can write off using double-declining-balance depreciation is 20% of the original \$10,000,000 basis:

$$D_{2005} = (0.2) BV_{t-1} = (0.2) B = (0.2) $10,000,000 = $2,000,000$$

So the new book value at the end of 2005 is

$$BV_{2005} = B - D_t = \$10,000,000 - \$2,000,000 = \$8,000,000$$

At the end of 2006, the depreciation amount is 20% of this new book value:

$$D_{2006} = (0.2) BV_{2005} = (0.2) \$8,000,000 = \$1,600,000$$

and the book value drops to

$$BV_{2006} = BV_{2005} - D_{2006} = \$8,000,000 - \$1,600,000 = \$6,400,000$$

At the end of 2007, the depreciation amount is 20% of this updated book value:

$$D_{2007} = (0.2) BV_{2007} = (0.2)$$
\$6,400,000 = \$1,280,000

and the book drops to

$$BV_{2007} = BV_{2006} - D_{2007} = $6,400,000 - $1,280,000 = $5,120,000$$

It would, of course, have been much easier to just calculate the book value directly from the initial basis, keeping in mind that 2007 was Year 3 of the recovery period:

$$BV_{2007} = (1 - d)^3 B = (0.80)^3 \$10,000,000 = \$5,120,000$$

Either way, the depreciation amount for 2008 will be 20% of this amount:

$$D_{_{2008}} = d \cdot BV_{_{2007}} = 0.2 (\$5, 120, 000) = \$1, 024, 000$$

Note that the book value at the end of 2014 (Year 10 of the recovery period) would be

$$\mathsf{BV}_{2014} = \left(0.80\right)^{10} \$10,000,000 = \$1,073,742$$

This *implied salvage value* is more than twice the \$500,000 that Ferryman assumed for the salvage value of the mill, which means Ferryman won't fully recover the cost by the end of the recovery period. Instead, when they scrap the mill, they'll take the difference between the *implied* salvage value and the *actual* salvage value and claim it as a capital loss.

Declining-Balance-Switching-To-Straight-Line Depreciation

To get around the problem of never fully recovering the initial cost of the asset, the decliningbalance and straight-line methods can be combined.

At the end of each year, the depreciation is computed using the declining-balance method:

$$D_t = d \cdot BV_{t-1}$$

It is also computed using straight-line depreciation **on the remaining balance**:

$$\mathsf{D}_{\mathsf{t}} = \frac{\mathsf{BV}_{\mathsf{remaining}} - \mathsf{S}}{\mathsf{n}_{\mathsf{remaining}}} == \frac{\mathsf{BV}_{\mathsf{t}-1} - \mathsf{S}}{\mathsf{n} - (\mathsf{t} - 1)}$$

The larger of the two depreciation amounts is the one used for that period.

In the early years, the declining-balance amount is always larger and in the later years, the straight-line amount is always larger, so there is always a point at which you switch from one method to the other (thus the name). Once you've made the switch, your final book value is guaranteed to be the assumed salvage value because that's the value you're aiming for.

For example, assume a piece of equipment is purchased for \$8.4^M and is to be depreciated over 5 years using double-declining-balance switching to straight-line depreciation. Assume, too, that the salvage value at the end of the 5 years is \$0.4^M.

Under DDB depreciation, the depreciation rate is

$$d = (2)\frac{100\%}{n} = \frac{200\%}{5} = 40\%$$

If just use standard DDB depreciation and don't switch, the implied salvage value is

$$\mathsf{BV}_{5} = (1 - 0.40)^{5} \$8.4^{\mathsf{M}} = (0.60)^{5} \$8.4^{\mathsf{M}} = \$0.65^{\mathsf{M}}$$

This is more than the actual salvage value, so we're leaving money on the table. We're not depreciating the entire amount we're entitled to. If we use declining balance switching to straight line, instead, the calculations are as follows:

For Year 1, the depreciation amount based on double-declining-balance depreciation is

 $D_1 = d \cdot BV_0 = (0.4) \$8.4^{M} = \$3.36^{M} (DDB)$

and the amount based on straight-line depreciation is

$$D_{1} = \frac{BV_{0} - S}{n_{remaining}} = \frac{\$8.4^{M} - \$0.4^{M}}{5} = \$1.60^{M} \text{ (SL)}$$

Since the former is larger, we write off \$3.36M, reducing the book value to

$$BV_1 = \$8.4^{M} - \$3.36^{M} = \$5.04^{M}$$

For Year 2, the depreciation amounts are

$$\begin{split} D_2 &= d \cdot BV_1 = \left(0.4\right) \$5.04^{\text{M}} = \$2.016^{\text{M}} \text{ (DDB)} \\ D_2 &= \frac{BV_1 - S}{n_{\text{remaining}}} = \frac{\$5.04^{\text{M}} - \$0.4^{\text{M}}}{4} = \$1.160^{\text{M}} \text{ (SL)} \end{split}$$

The former is still larger so we write off \$2.016M, reducing the book value to

$$BV_2 = \$5.04^{\text{M}} - \$2.016^{\text{M}} = \$3.024^{\text{M}}$$

For Year 3, the depreciation amounts are

$$D_{3} = d \cdot BV_{2} = (0.4) \$3.024^{M} = \$1.210^{M} \text{ (DDB)}$$
$$D_{3} = \frac{BV_{2} - S}{n_{\text{remaining}}} = \frac{\$3.024^{M} - \$0.4^{M}}{3} = \$0.875^{M} \text{ (SL)}$$

The former is still larger so we write off \$1.210M, reducing the book value to

$$BV_3 = $3.024^{M} - $1.210^{M} = $1.814^{M}$$

For Year 4, the depreciation amounts are

$$D_4 = d \cdot BV_3 = (0.4)$$
\$1.814^M = \$0.726^M (DDB)

$$D_{4} = \frac{BV_{3} - S}{n_{remaining}} = \frac{\$1.814^{M} - \$0.4^{M}}{2} = \$0.707^{M} (SL)$$

The former is still larger (barely) so we write off \$0.726M, reducing the book value to

$$BV_4 = \$1.814^{\text{M}} - \$0.726^{\text{M}} = \$1.088^{\text{M}}$$

Finally, for Year 5, the depreciation amounts are

$$D_5 = d \cdot BV_4 = (0.4)$$
\$1.088^M = \$0.435^M (DDB)

$$D_{4} = \frac{BV_{3} - S}{n_{remaining}} = \frac{\$1.088^{M} - \$0.4^{M}}{1} = \$0.688^{M} (SL)$$

This time the latter is larger so we write off \$0.688^M, reducing the book value to

$$BV_{4} = \$1.088^{M} - \$0.688^{M} = \$0.40^{M}$$

which was the original salvage value of the equipment. So we've depreciated the entire amount we were entitled to.

There is a .pdf file on the website called "Ferryman Depreciation Slides" that shows plot of book value over time for all of the methods we've looked at, including a year-by-year look at how declining-balance-switching-to-straight-line depreciation works for that example problem.

We won't have any homework or test problems on declining-balance-switching-to-straight-line depreciation because it's so tedious to calculate, but you need to be aware of it because it's the method used in MACRS depreciation, which is the next (and final) lecture topic.