Course Title

Engineering Economic Analysis

Chapter 7

Depreciation

Lecture 12 (Week 12)

Concept and terminologies of depreciation, Basic methods of depreciation

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Learning Objective

From studying this chapter the students will be able to understand on the topics:

- Concept of depreciation its causes and terminologies
- Basic methods used in depreciation analysis
  - Straight line depreciation
  - Declining balance depreciation
  - Sum of the year digit (SOYD) depreciation
  - Sinking fund depreciation
  - Modified accelerated cost recovery system (MACRS)

7.1 Concept of depreciation

Depreciation is the gradual reduction in the value of an asset due to wear and tear, usage, passage of time, obsolescence, depletion or inadequacy. [1]In economic analysis, value may refer to either market value or value to the owner. A non-cash expense that reduces the value of an asset as a result of wear and tear or age and obsolescence. Most assets lose their value over time (in other words, they depreciate), and must be replaced once the end of their useful life is reached. When an asset is installed and used, it reduces its value in terms of money due to ageing. It is an accounting concept that establishes an annual deduction against before tax income such that the effect of time and use on asset's value can be reflected in a firm's financial statements. [2]Engineers need to learn about depreciation because their design decisions can affect the way investments and annual operating costs are treated from an income tax perspective.

Depreciation charges are a convenient mechanism for recovering the capital that is invested. As such, when the time comes to replace an asset, funds will be available to do so (unless prices have increased over the asset's life). Also, treating depreciation charges as expenses allows one to incorporate such charges in the cost of production and ensure that prices are sufficient to recover invested capital. In general, assets can only be depreciated if they meet the following basic requirements:

- The property must be used for business purpose to produce income.
- The property must have a useful life that can be determined and this life must be longer than one year.
- The property must be an asset that decays, gets used up, wears out, becomes obsolete, or loses value to the owner from natural causes.

7.2 Causes of depreciation

1. **Wear and tear**

- Also called physical depreciation. The continuous use of an asset makes it old and ineffective.

2. **Effusion of time**

- With the passage of time, the value of some assets diminishes, even if they are not used in the business.

3. **Obsolescence**

- An asset may lose its usefulness due to improvement it technology. Also called functional depreciation.

4. Sudden failure

- It refers to sudden or catastrophic loss in value due to technological characteristics inherent in the asset. [3]
- It also includes the loss due to accident or misuse.

5. Depletion

- An assets may get exhausted due to its excessive consumption which causes in gradual decrease in the quantity which is depletion.
- Removal of oil, timber, rock or minerals from a site decreases the value of holding

7.3 Classification of Depreciation

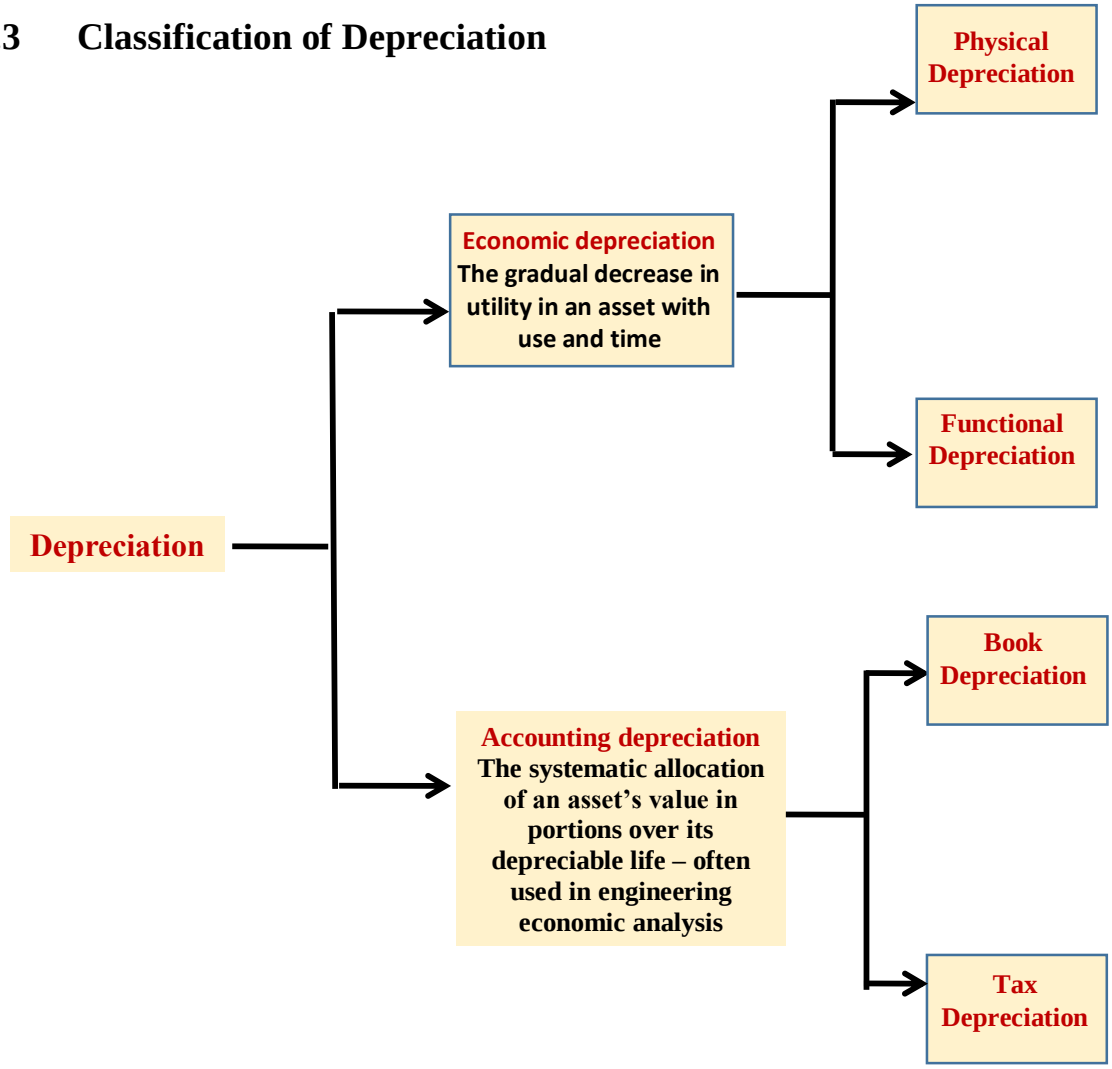

Fig 7.1 Classification of depreciation [4]

1. **Economic depreciation**

- It refers the gradual decrease in the economic value/utility of fixed assets like equipment, vehicles, with passage of time and wear and tear.

(a) Physical depreciation

- It occurs in any fixed asset due to wear and tear from use and deterioration from interaction with environment like corrosion.

(b) Functional depreciation

- It occurs as a result of change in technology that decreases or eliminates the need for an asset.

Accounting Depreciation

The systematic allocation of the initial cost of an asset in parts over a time, known as its depreciable life and is done by the accounting depreciation. [4] This method of depreciation in exclusively used in engineering economic analysis as it provides basis for determining the income taxes associated with any project undertaken. Two methods are applied for accounting depreciation i.e. book depreciation method (used by business for financial accounting) and tax depreciation method (used in tax calculation per government regulations)

7.4 Characteristics of depreciation

The depreciation charged on fixed assets has the following features:

- Depreciation is always charged on fixed assets except land.
- Depreciation causes gradual and continuous fall in the value of an asset.
- Depreciation is a continuous process and it does not matter whether the asset was put to use during the period or not.
- Depreciation is the fall in the book value of the asset and not in the market value of the asset.
- Depreciation is charge against revenue of an accounting period.
- Depreciation is the result of the use of assets, passage of time and obsolescence.
- Total depreciation of an asset cannot exceed its depreciable value (cost less scrap value)

7.5 Terminologies of Depreciation

1. Cost basis or Unadjusted Cost

Initial cost of the assets including purchase price, delivery and installation fees, and other depreciable direct costs incurred to prepare the asset for use.

2. Book Value

Represents the remaining, un-depreciated capital investment on the books after the total amount of depreciation charges to date have been subtracted from the basis. [5]The book value is usually determined at the end of each year.

3. Recovery period

The number of years over which the basis of property is recovered through the accounting process. It is the depreciable life n in years

4. Salvage Value (SV)

It is the estimated value of the property at the end of the asset's depreciable life. It is the expected selling price of a property when the asset can no longer be used productively by its owner.

5. Market Value

It is the estimated amount of money that are bought and sold in the open market. It is the amount that is paid by willing buyer to will seller for a property.

6. Useful Life

It the estimated time that the property can be kept into business and trade to produce income. It is also sometimes called depreciable life.

7.6 Methods of Depreciation

1. **Book Depreciation Method (used by business for financial accounting)**
   - (a) Straight line Method
   - (b) Accelerated Method
     - (i) Declining balance Method
     - (ii) Sum of the Year's Digit Method.
     - (iii) Sinking Fund Method
2. **Tax Depreciation Methods (used in tax calculation per government regulations)**
   - (a) Accelerated Cost Recovery System (ACRS)
   - (b) Modified Accelerated Cost Recovery Systems. (MACRS)

Book Depreciation

1. **Straight – Line Method (SL)**

It is the simplest and most often used depreciation method. It assumes that a constant amount is depreciated each year over the depreciable (useful life) of the asset. In this method, a fixed or equal sum or amount is charged as the depreciation amount throughout the lifetime of the asset such that the accumulated sum at the end of the life of the asset is exactly equal to the purchase value of the cost, i.e. the value of the assets will become zero

$$(D_n) = (I - S)/ N$$

Where,

D_n = Depreciation charge during year n

I = Cost of the assets including installation expenses

S = Salvage value at the end of useful life

N = Useful life

Book Value in a given year = Cost Basis – total depreciation charges made to date

Example 7.1

Consider the following automobile data:

Cost of the asset, (I) = $ 10,000, Useful life (N) = 5 years, Estimated Salvage value (S) = $ 2,000

Compute the annual depreciation allowance and the resulting book value using the straight line depreciation method?

Given: I = $10,000, S = $2,000, N = 5 years

Find: D_n and B_n for n =1 to 5

The straight line depreciation rate is 1/5 or 20%.

Therefore the annual depreciation charge is

D_n = (0.20) ($10,000 - $2000) = $ 1600

n	B_{n-1} ($)	D_n ($)	B_n ($)
1	10,000	1600	8400
2	8400	1600	6800
3	6800	1600	5200
4	5200	1600	3600
5	3600	1600	2000

2. **Accelerated Method**

Depreciation methods that provide for a higher depreciation charge in the first year of an asset's life and gradually decreasing charges in subsequent years are called accelerated depreciation methods.

(i) Declining balance Method (DB)

Declining balance is also known as the fixed percentage or uniform percentage method. In this method, Book value is multiplied by the fixed rate

$$\alpha = (1/N)\ multiplier$$

The most commonly used multipliers is double the straight line rate i.e ($\alpha = (1/N) *2$, for this reason it is called Double Declining Balance Method.

Example 7.2

Consider the following accounting information for a computer system.

Cost of the asset (I) = $ 10,000, Useful life (N) = 5 years, Estimated Salvage Value (S) = $778

Compute the annual depreciation allowances and the resulting book values using the double declining deprecation method.

- The book value at the beginning of the first year is $ 10,000.
- The declining balance rate (α) is (1/5) *2 = 40%
- The depreciation deduction for the first year will be $ 4000 (40%* $10,000 = $4000)
- The book value at the beginning of the second year is $10,000 - $4000 = $6000
- The depreciation deduction for the second year will be $ 2,400 (40% * $ 6,000 = $2,400)
- The book value at the beginning of the third year is 6, 000 – 2400 = $ 3,600
- On continuing this process, we obtain the depreciation value and book value as shown in Table.

n	B_{n-1} ($)	D_n ($)	B_n ($)
1	10,000	4,000	6,000
2	6,000	2,400	3,600
3	3,600	1,440	2,160
4	2,160	8,64	1,296
5	1,296	5,18	7,78

Issues regarding Salvage Value

Salvage value (S) must be estimated at the beginning of depreciation analysis. In previous example, the final Book Value (B_N) equals to the estimated salvage value, an occurrence that is rather unusual in the real world. When $B_N \neq S$, we have to make the adjustments in our depreciation analysis methods. Two cases Arises:

Case 1: When $B_N > S$

Case 2: when $B_N < S$

Case 1: When $B_N > S$

When $B_N > S$, is the situation in which we have not depreciated the entire cost of the asset. To reduce the book value of an asset to its salvage value as quickly as possible, it can be done by switching from declining balance (DB) to Straight line (SL). The switch from DB to SL depreciation can take place in any of the 'n' years (optimal year). The switching rule is:

'If depreciation by DB in any year is less than (or equal to) the depreciation by SL then we would switch to and remain with SL method for the duration of the project's depreciable life.' [4]

The straight line depreciation is any year n is calculated by

$$D_n = \frac{\text{book value at the beginning of year n} - \text{salvage value}}{\text{Remaining useful life at beginning of year n}}$$

Example 7.3

Consider the following accounting information for a computer system.

Cost of the asset (I) = $ 10,000, Useful life (N) = 5 years, Estimated Salvage Value (S) = $0

Declining balance Rate (α) = (1/5) *2 = 40%

Determine the optimal time to switch from DB to SL depreciation and the resulting depreciation schedule.

First, Computing the DDB depreciation for each year.

n	B_{n-1} ($)	D_n ($)	B_n ($)
1	10,000	4,000	6,000
2	6,000	2,400	3,600
3	3,600	1,440	2,160
4	2,160	8,64	1,296
5	1,296	5,18	7,78

Here the Book value is $778 at the end of Year 5 which is Greater than salvage value. Therefore we use the switching fundamentals.

Second, we compute the SL depreciation for each year then compare SL to DDB depreciation for each year and use the decision rule for when to change.

n	SL Depreciation	DDB Depreciation	Decision
1	(10000-0)/5 = 2000	<4000	Do not switch
2	(6000 -0)/4=1500	<2400	Do not switch
3	(3600 -0) /3 = 1200	<1440	Do not switch
4	(2160- 0) 2 = 1080	>864	Switch to SL

The optimal year for switching is year 4

Third, use the SL depreciation method for the remaining depreciable year from the optimal year. The depreciation schedule is

Year	DDB with switching to SL ($)	End of Year Book Value (Rs)
1	4000	6000
2	2400	3600
3	1440	2160
4	1080	1080
5	1080	0

Case 2: $B_N < S$

When $B_N < S$, we must re-adjust our analysis because tax law doesn't permit us to depreciate the asset below their salvage value. [4]If the book value is lower than S, at any period, then the depreciation amount are adjusted so that $B_N = S$.

(ii) Sum of the year digit (SOYD) method

This method results in larger than straight line depreciation charges during the early years of an asset and smaller charges as the asset nears the end of its estimated useful life. Each year depreciation charge is compound as the remaining useful life at the beginning of the year divided by the sum of the years digits for the total useful life. In this method, the number 1, 2, 3… N are summed, where N is the estimated years of useful life.

$$\mathbf{SOYD = 1+2+3+ \ldots\ldots\ldots + N = \{N\ (N+1)\}/2}$$

$$\mathbf{SOYD\ Depreciation\ (D_n) = \frac{\{N - n + 1\}\ (I - S)}{SOYD}}$$

Example 7.4

Compute the SOYD depreciation schedule for the following data:

Cost of the asset (I) = $ 10,000, Useful life (N) = 5 years, Estimated Salvage Value (S) = $2000

We first compute the sum – of – years' digits (SOYD) = 1+2+3+4+5 = 5 (5+1) / 2 = 15

End of Year	D_n ($)	B_n ($)
1	5/15 (10,000 – 2,000) =2,667	10,000 – 2,667 = 7, 333
2	4/15 (10,000 – 2,000) =2,133	7, 333– 2,133 = 5,200
3	3/15 (10,000 – 2,000) =1,600	5,200– 1,600 = 3,600
4	2/15 (10,000 – 2,000) =1,067	3,600 – 1,067 = 2,533
5	1/15 (10,000 – 2,000) =5,33	2,533– 5,33 = 2,000

(iii) Sinking Fund Method

Sinking fund method is a method of calculating depreciation for an asset in which apart from calculating depreciation, it also keeps aside a fund for replacing the asset at the end of its useful life. [6]In this method of depreciation, the book value decreases at increasing rates with respect to the life of the asset. The fixed sum depreciated at the end of every time period earns an interest at the rate of i% compounded annually.

Example 7.5

Compute the depreciation charge and book value in each year using sinking fund method.

Cost of the asset = $ 1, 00,000, Salvage value = $ 20,000

Life of the asset (N) = 8 years, Interest rate (i) = 12%

Fixed or the annual depreciation charge

A = (P-F) (A/F, 12%, 8) = (1, 00, 000 – 20, 000) (0.0813) = $6,504

Depreciation at the end of 1st year (D_1) = $ 6,504

Depreciation at the end of 2nd year (D_2) = 6,504 + (6,504 *0.12) = $ 7284.48

Depreciation at the end of 3rd year (D_3) = {6,504 + (6,504 + 7,284.48) *0.12} = $. 8,158.62

Depreciation at the end of 4th year (D_4) = {6,504 + (6,504 + 7,284.48+8,158.62) *0.12} = $ 9,137.65

EOY	Fixed depreciation	Net depreciation ($)	Book value ($)
0	6, 504		1,00,000
1	6, 504	6, 504.00	93,496.00
2	6, 504	7,284.48	86,211.52
3	6, 504	8,158.62	78,052.90
4	6, 504	9,137.65	68,915.25
5	6, 504	10,234.17	58.681.08
6	6, 504	11,462.27	47,218.81
7	6, 504	12,837.74	34,381.07
8	6, 504	14,378.27	20,002.80

2. **Tax Depreciation Method**

Modified Accelerated Cost Recovery System (MACRS)

In 1980, the U.S. introduced MACRS as the required tax depreciation method for all depreciable assets. [5]Historically, for the tax purposes as well as for accounting, an asset's depreciable life was determined by its estimated useful life i.e. an asset would be fully depreciated at approximately the end of its useful life. The MACRS scheme, totally abandon this practice and simpler guidelines

were set which created several classes of assets, each with more or less arbitrary life called Recovery Period. [4]The MARCS scheme includes 8 categories of assets: 3 year, 5 year, 7 year, 10 year, 15 year, 20 year, 27.5 year and 39 year.

The salvage value of property is always treated as zero.

Half year Convention

- The MACRS scheme uses the half-year convention i.e. it is assumed that all assets are placed in service at mid-year and they have zero salvage value.
- Only half year depreciation is allowed for the first year of the asset placed in service.
- With half year's depreciation being taken in service, a full year's depreciation is allowed in each of the remaining years of the assets recovery period.
- Finally the remaining half year depreciation in the year following the end of the recovery period.

Switching from Declining Balance to Straight Line Method

1. The MACRS asset is depreciated initially by the Declining balance (DB) method and then Straight line method.
2. It adopts the switching convention as discussed in the previous section.

MACRS Property Classification

Recovery Period	Applicable Property
3 year	Special tools for manufacture of plastics products, metal products and motor vehicle
5 year	Automobiles, light trucks, equipment used of R&D, computerized telephone switching systems.
7 year	Manufacturing equipment, office furniture.
10 year	Vessels, barges, tugs
15 year	Waste water plants, telephone distribution plants
20 year	Municipal sewers, electrical power plants
27.5 year	Residential rental property
39 year	Non-residential real property including elevators and escalators

Table Source: [4]

Example 7.6

A tax payer wants to place in service a $ 10,000 asset that is assigned to the 5 year class. Compute the MACRS percentage and depreciation amounts for the asset.

MACRS deduction percentages, beginning with the first taxable year and ending with the 6^{th} year is

Straight line rate = 1/5 = 0.20, Double declining balance rate. (α) = 1/5 *200% = 40%

Under MACRS, salvage value = 0

Year	Calculation (%)	MACRS %	Decision
1	½ year DDB dep. = (0.5) (0.4) (100%)	20%	
2	DDB dep. = (0.4) (100% -20%) SL dep. (1/4.5) (100% -20%)	32% 17.78%	Do not switch
3	DDB dep. = (0.4) (100% - 52%) SL dep. (1/3.5) (100% -52%)	19.20% 13.71%	Do not switch
4	DDB dep. = (0.4) (100%-71.20%) SL dep. (1/2.5) (100% -71.20)	11.52% 11.52%	Switch to SL
5	SL dep. (1/1.5) (100% - 82.72%)	11.52%	
6	½ year SL dep. = (0.5) (11.52%)	5.76%	

In the year 4, SL depreciation is ≥ DDB depreciation and we switch to SL.

Calculate the depreciation amounts from the percentages

Year (n)	MARCS Percentage (%)		Depreciation basis	Depreciation Amount (D_n)
1	20	*	$10,000	$2,000
2	32	*	$10,000	$3,200
3	19.20	*	$ 10,000	$1,920
4	11.52	*	$ 10,000	$ 1,152
5	11.52	*	$ 10,000	$ 1,152
6	5.76	*	$ 10,000	$576

Depreciation Schedule

n	B_{n-1} ($)	D_n ($)	B_n ($)
1	10000	2000	8000
2	8000	3200	4800
3	4800	1920	2880
4	2880	1152	1728
5	1728	1152	576
6	576	576	0

References:

[1] *Engineering Economics and Costing:* Dr. K.K. Patra & Dhiraj Bhattacharjee, First Edition, S. Chand and Company Ltd, 2013.

[2] *Engineering Economy:* William G. Sullivan, James A. Bontadelli & Elin M. Wicks, Eleventh Edition, Pearson Educations, Inc. 2000.

[3] *Engineering Economics:* James L. Riggs, David D. Bedworth and Sabah U. Randhawa, Fourth Edition, Tata McGraw Hill Education Private Limited, New Delhi, India, 2004.

[4] *Contemporary Engineering Economics*, Chan S. Park Second Edition, Addison-Wesley Publishing Company, 1997.

[5] *Basics of Engineering Economy:* Leland Blank and Anthony Tarquin, Indian Edition, Tata McGraw Hill Education Private Limited, New Delhi, India, 2013.

[6] https://byjus.com/commerce/sinking-fund-method/ (Viewed November 2022)