Economic decision analysis –GSOE9830

T2-2025

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To This Point We Have Assumed a High Degree of Confidence in Estimated Values

- Assumed Certainty:
  - The degree of confidence in available information.
- Decisions Under Certainty:
  - Decisions made based on assumed certainty analysis.
- Key Point:
  - In nearly all situations, ultimate economic results remain unknown.

Why Does Uncertainty Matter in Engineering Decisions?

Engineering decisions often involve estimates (costs, revenues, time).

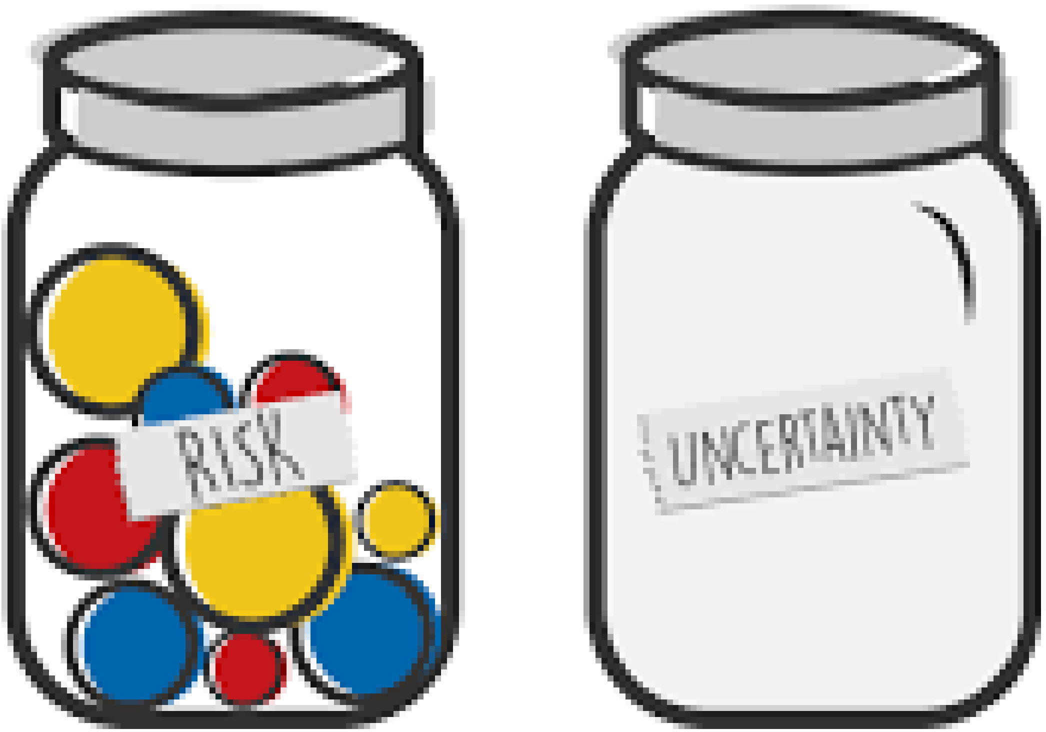
These values are rarely known with certainty.

Uncertainty can change project outcomes significantly.

We must learn how to model and respond to it.

Decision Making Is Fraught with Risk and Uncertainty

- **Decisions Under Risk:**
  - The decision maker can estimate probabilities of specific outcomes.
- **Decisions Under Uncertainty:**
  - Estimates of probabilities for various unknown future states cannot be determined.



Four Major Sources of Uncertainty Are Present in Engineering Economy Studies

- Possible inaccuracy of cash-flow estimates
- The type of business involved in relation to the future health of the economy
- The type of physical plant and equipment involved
- The length of the study period used in the analysis

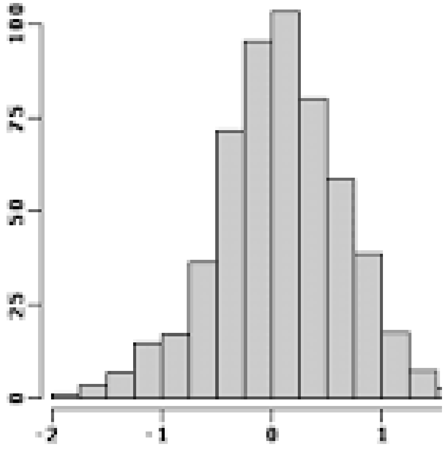
Risk Analysis

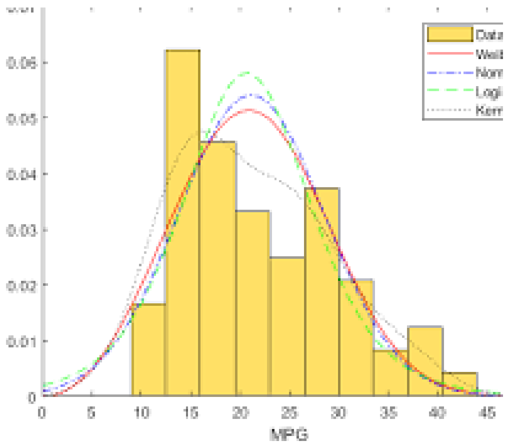
Uncertainty in input variables

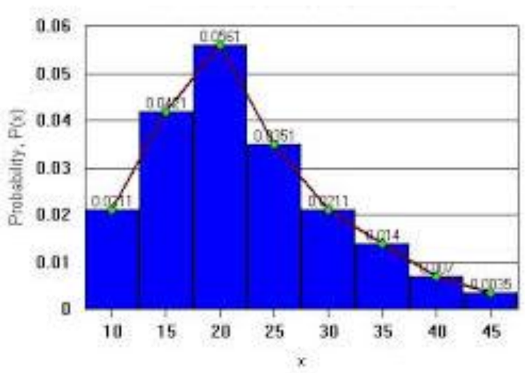
- **Key Input Variables:**
- **Cost Estimates:**
    - Fluctuations in material, labor, and overhead costs.
- **Revenue Projections:**
    - Variability in sales forecasts and market demand.
- **Interest Rates:**
    - Changes in borrowing costs and investment returns.
- **Inflation Rates:**
    - Unpredictable shifts in purchasing power and price levels.

Uncertainty in input variables

Net cash flow=Revenues – Costs - Taxes





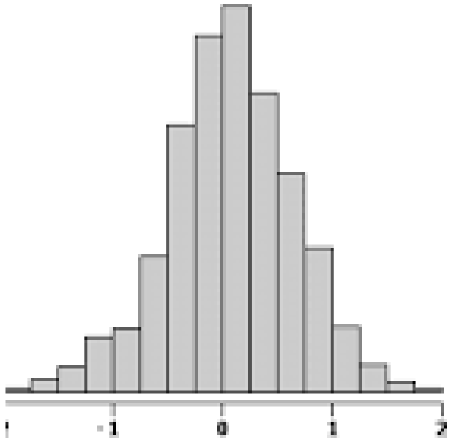


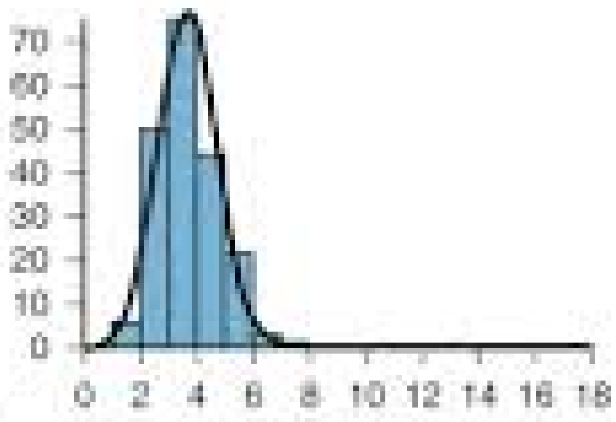
Estimating Revenue

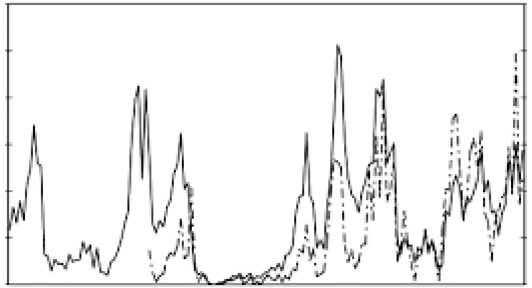
- Revenue uncertainty refers to the unpredictability in forecasting future sales and income.
- **Key Factors Contributing to Revenue Uncertainty:**
- **Market Demand Fluctuations:**
  - Changes in consumer preferences and behavior.
- **Economic Conditions:**
  - Economic growth, recession, and overall market stability.
- **Competition:**
  - Actions and strategies of competitors affecting market share.
- **Pricing Strategies:**
  - Effects of pricing changes on consumer purchasing decisions.

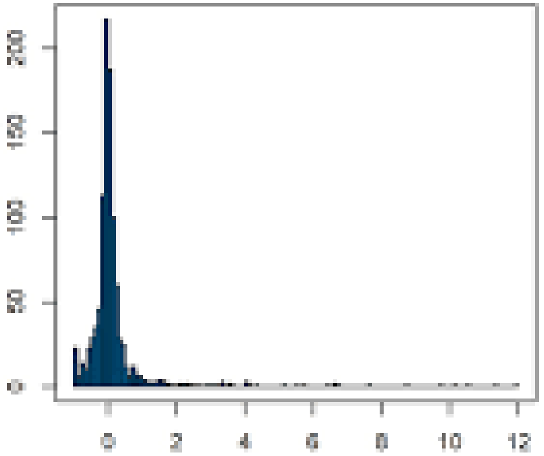
Estimating Revenue

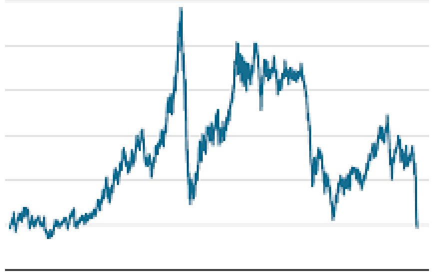
- Revenue: Sales Volume × Price



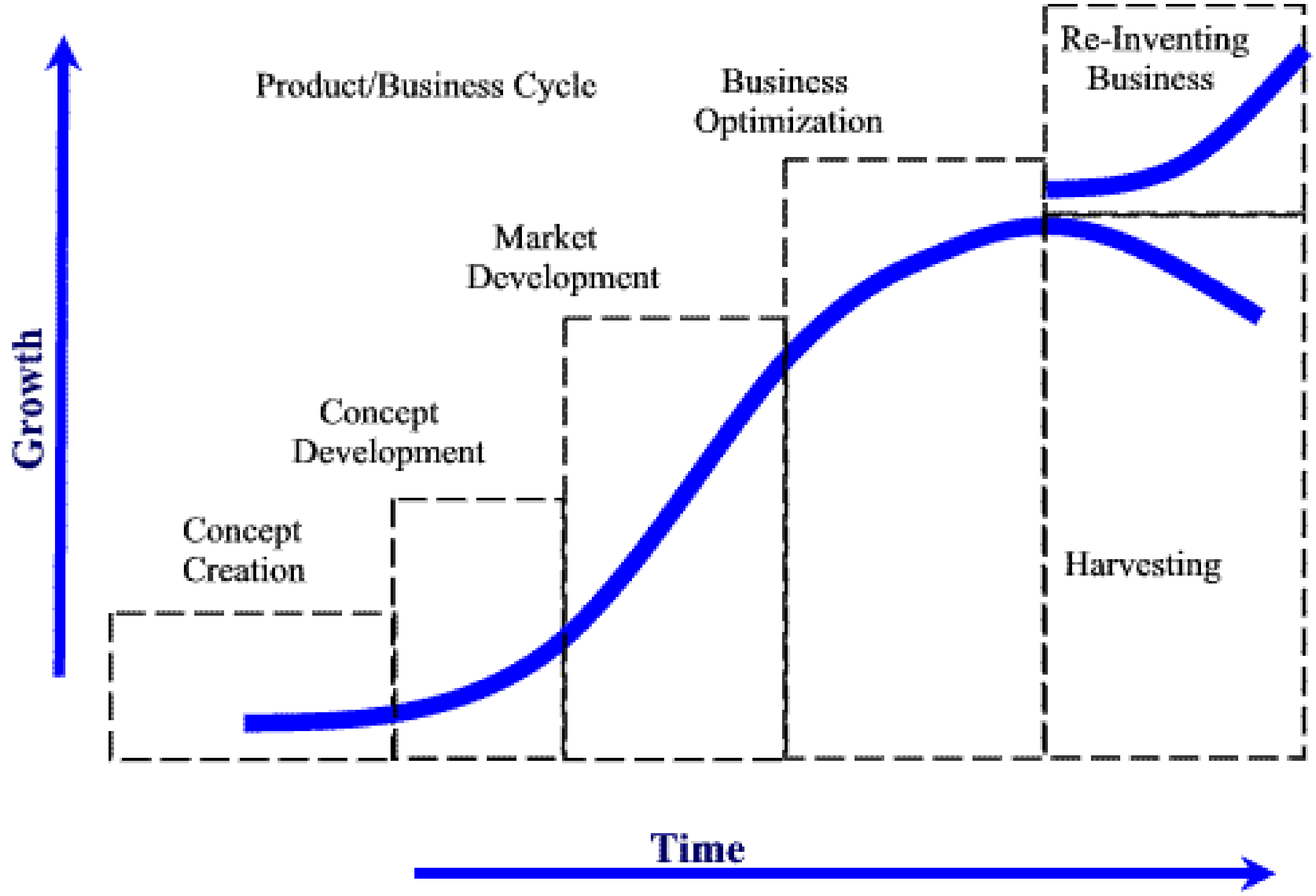








Estimating sales volume

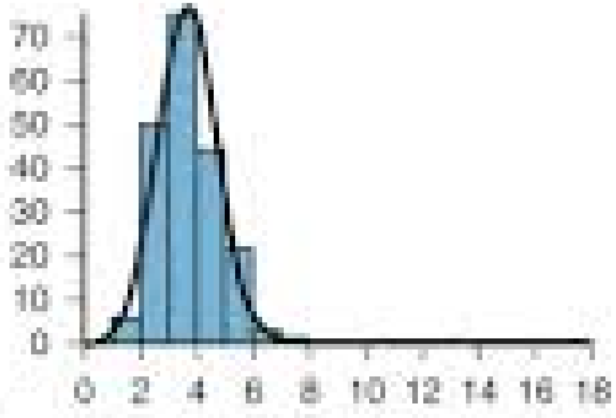


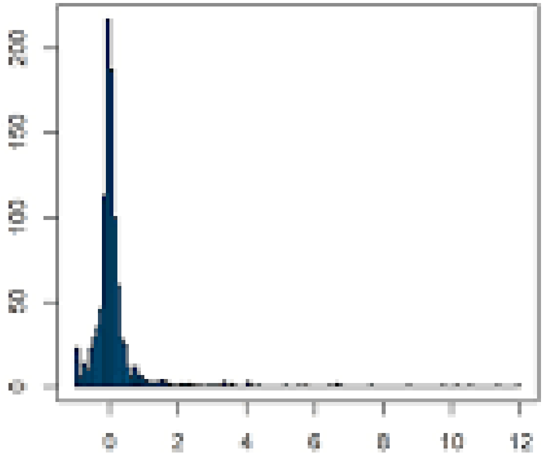
Estimating cost

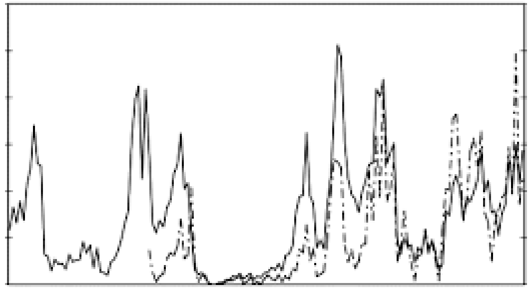
- **Definition:**
- Cost overruns occur when actual project expenses exceed the budgeted costs.
- **Common Causes of Cost Overruns:**
- **Poor Planning:**
  - Inadequate estimation of resources, time, and expenses.
- **Scope Changes:**
  - Modifications to project scope leading to additional costs.
- **Unexpected Challenges:**
  - Unforeseen issues such as technical difficulties or supply chain disruptions.
- **Inflation:**
  - Rising prices for materials, labor, or services over time.

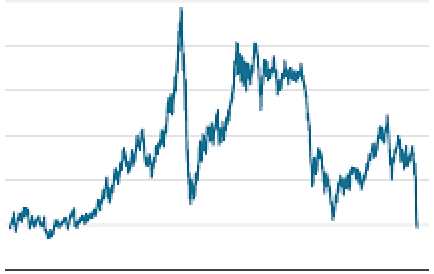
Estimating cost

- Cost: Material + Tax + Transportation (fuel cost)+….

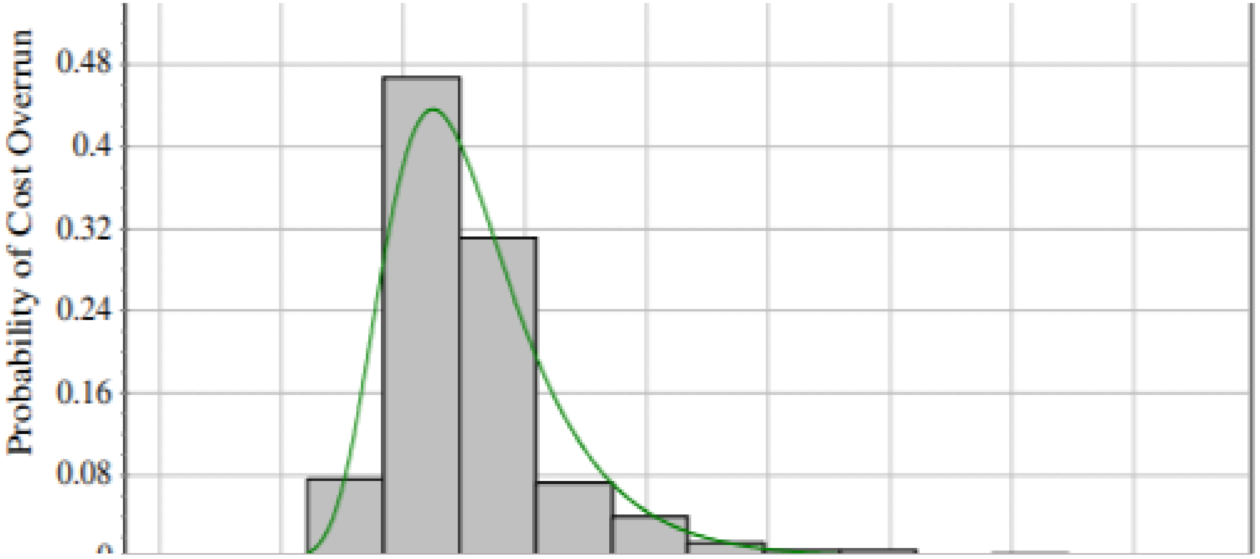








Cost overruns



Percentage of cost overrun

Love, P.E., Wang, X., Sing, C.P. and Tiong, R.L., 2013. Determining the probability of project cost overruns. *Journal of Construction Engineering and Management*, *139*(3), pp.321-330.

Project cost overruns

- Ahiaga-Dagbui, D.D. and Smith, S.D., 2014. Rethinking construction cost overruns: cognition, learning and estimation. *Journal of Financial Management of Property and Construction*.

Project	*Estimated Cost (in millions)*	*Final Cost (in millions)*	*% Overrun*
Sydney Opera House	AUD 7	AUD 102	1357
Nat West Tower	£15	£115	667
Thames Barrier Project	£23	£461	1904
Scottish Parliament	£195*	£414	112
British Library	£142	£511	260

*September 2000 estimate. Initially stated cost was about £40 million Source: Audit Scotland (2004)

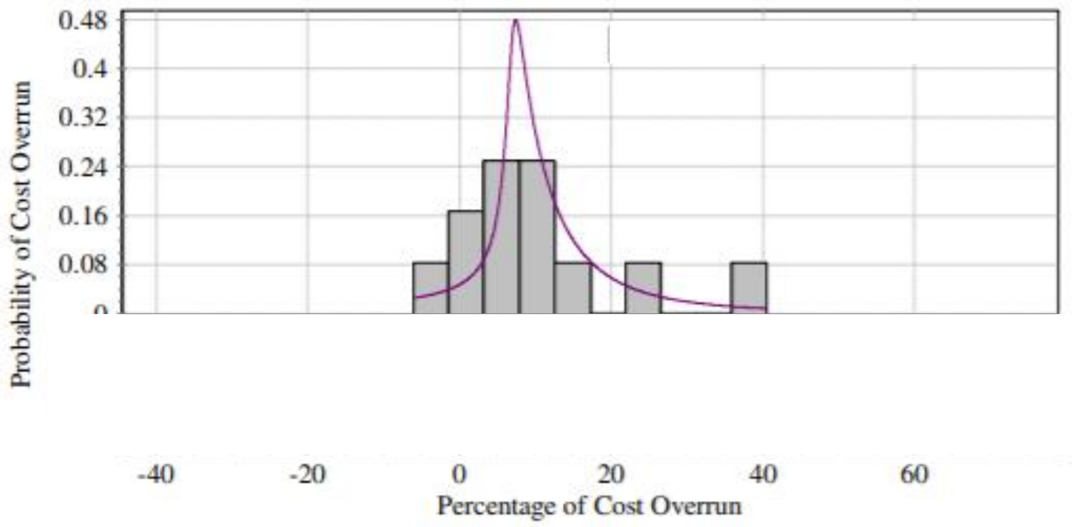
Project cost overruns

Project Cost Overruns by Project Type and Contract Value

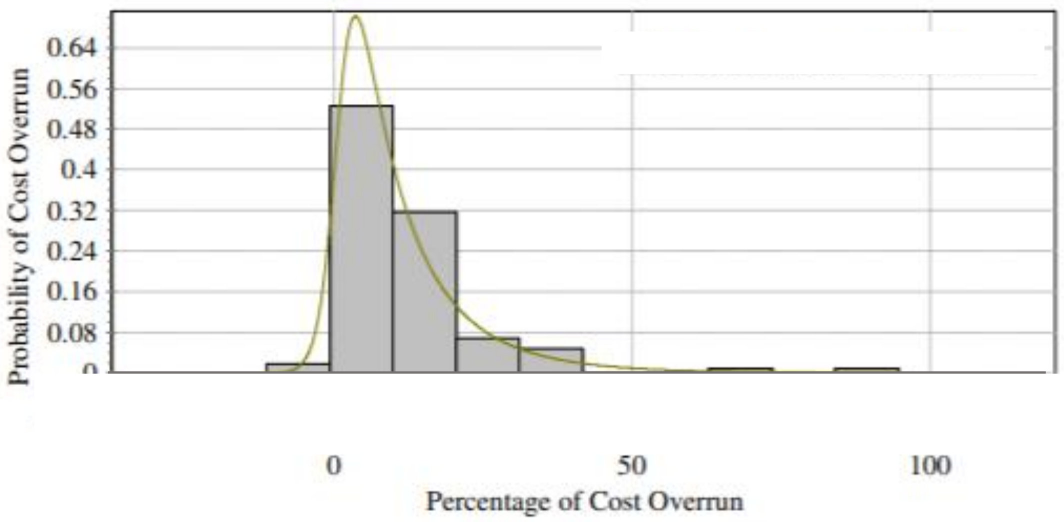
Project type	Project size	N	Mean O_{cv}	Mean percentage overrun (%)
Construction	<A$1 million	14	A$513,546	24.90
	A$1 to A$10 million	70	A$3,874,368	10.30
	A$11 to A$50 million	60	A$21,860,966	12.90
	A$51 to A$100 million	12	A$66,883,333	9.03
	A$101 to A$200 million	6	A$162,666,666	13.79
	>A$200 million	2	A$376,000,000	9.09
	Subtotal	161	A$25,521,927	12.56
Civil engineering	A$1 to A$10 million	61	A$8,136,604	14.01
	A$11 to A$50 million	43	A$24,906,930	8.49
	A$51 to A$100 million	7	A$77,285,714	7.90
	>A$101 million	4	A$165,250,000	9.10
	Subtotal	115	A$22,092,965	11.76
	Total	276	A$24,093,193	12.22

Ahiaga-Dagbui, D.D. and Smith, S.D., 2014. Rethinking construction cost overruns: cognition, learning and estimation. *Journal of Financial Management of Property and Construction*.

Cost overruns



construction and engineering projects less than A$101 million

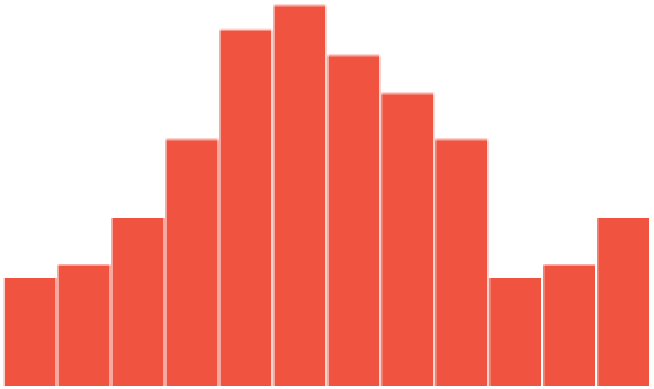


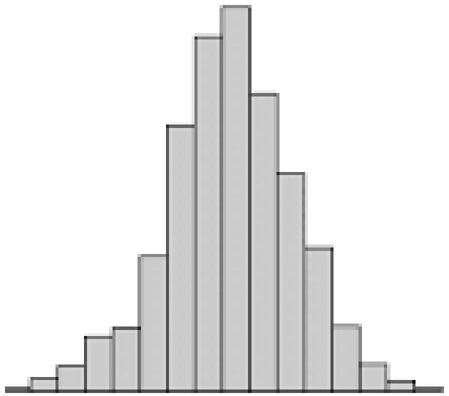
construction and engineering projects less than A$11–$50 million

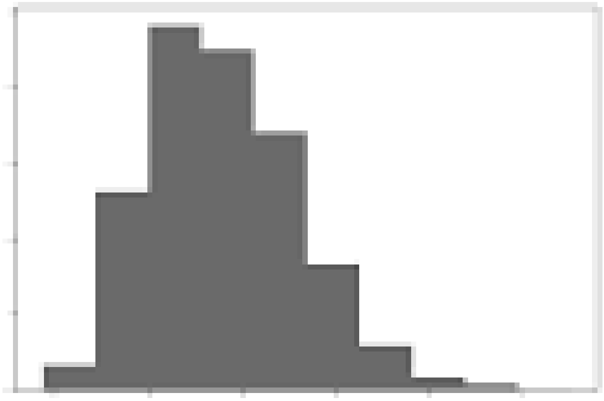
Love, P.E., Wang, X., Sing, C.P. and Tiong, R.L., 2013. Determining the probability of project cost overruns. *Journal of Construction Engineering and Management*, *139*(3), pp.321-330.

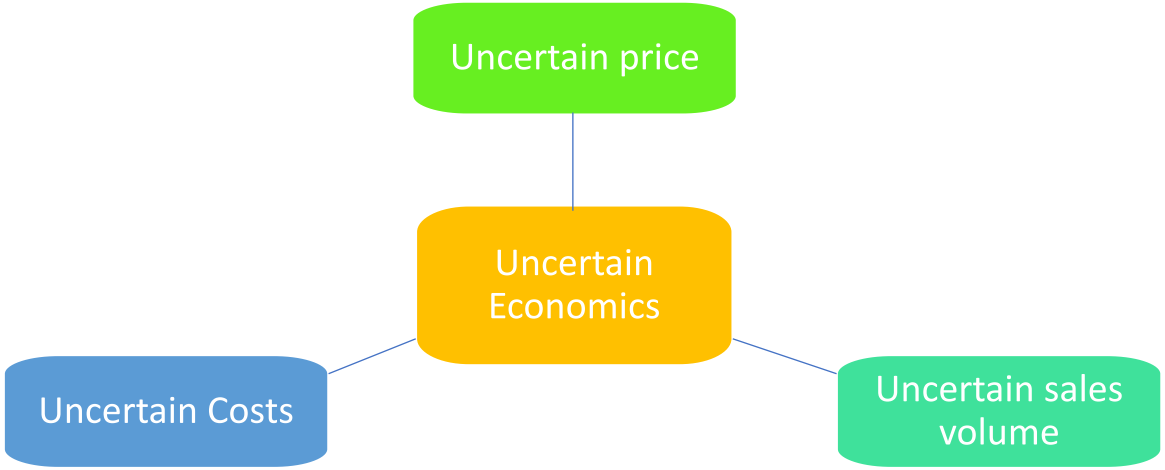
Estimating Profit

- Estimated Profit: Estimated revenue –Estimated cost



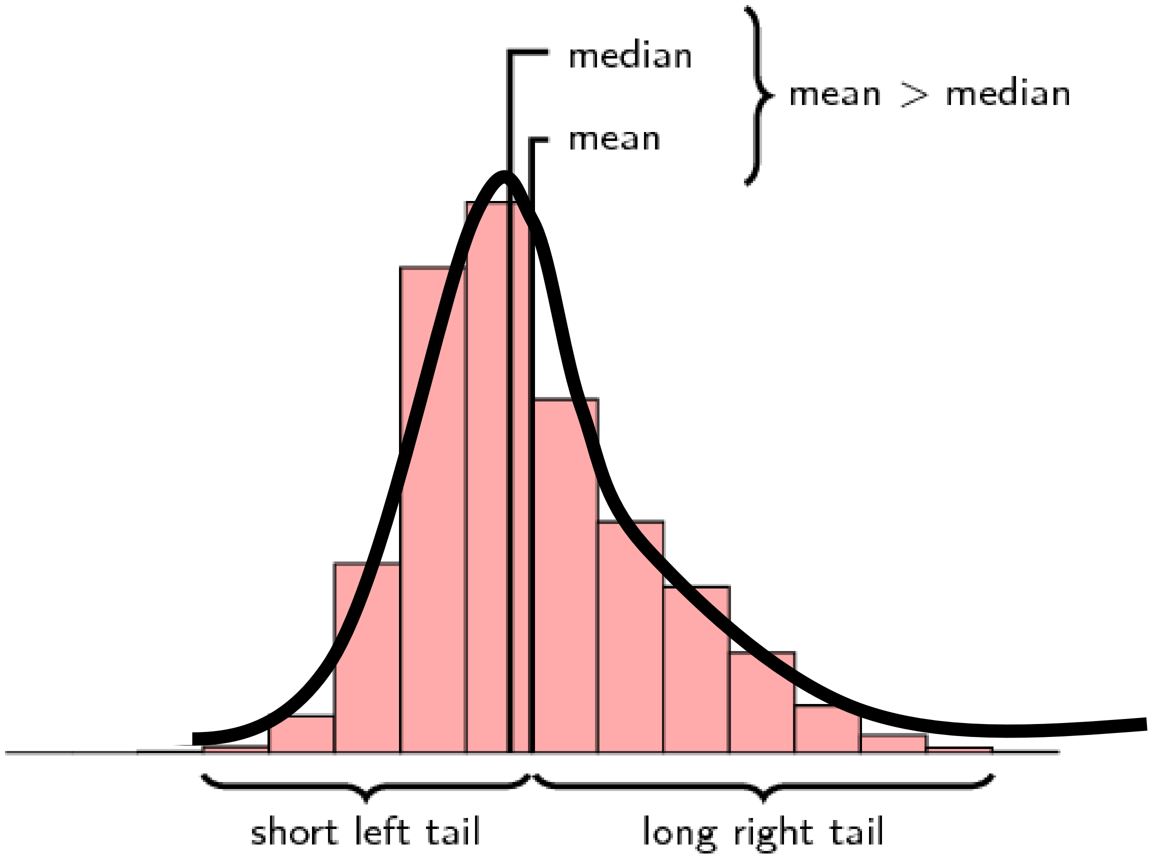






Probability distribution

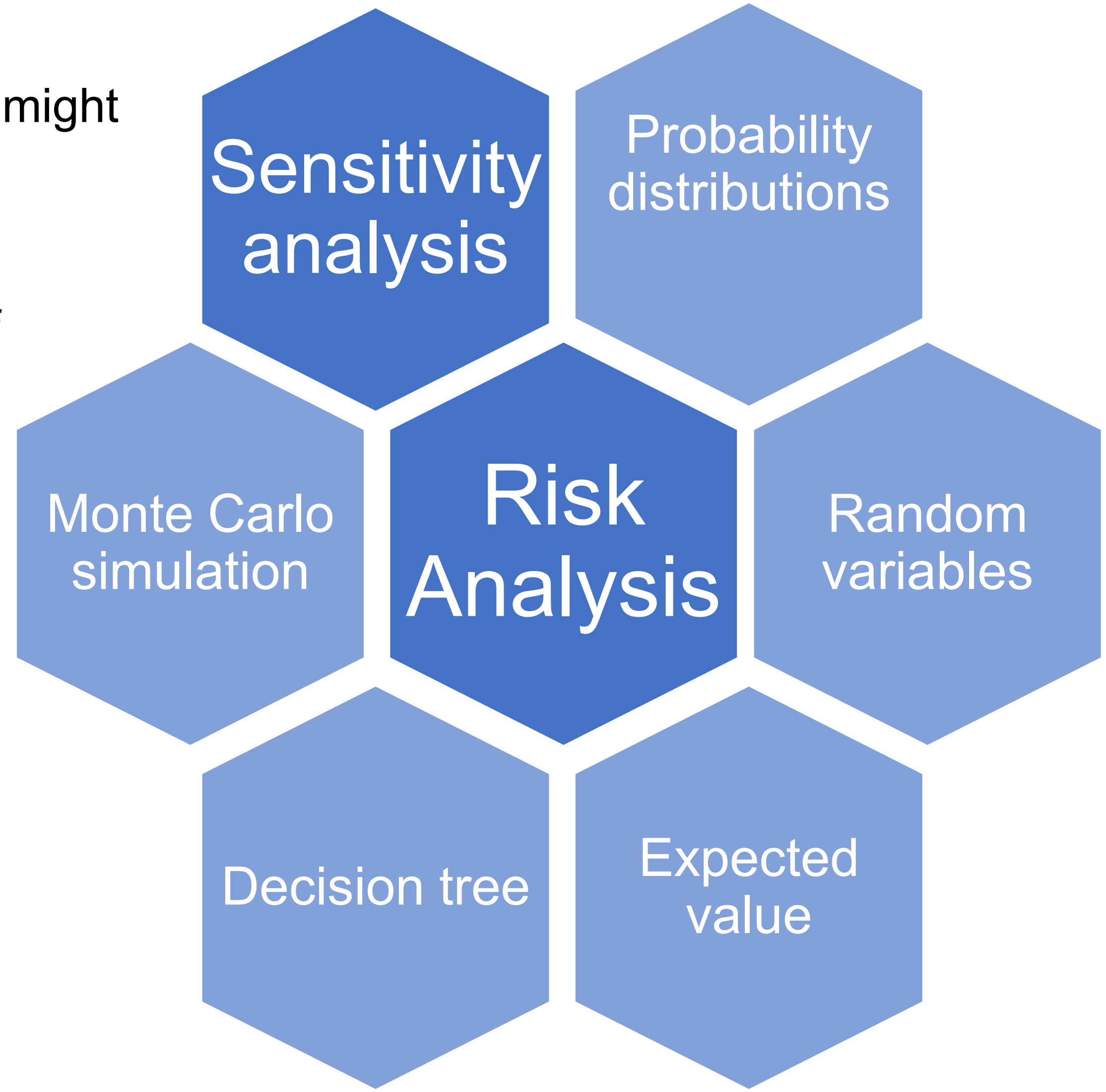
- A probability distribution is a mathematical function that describes the likelihood of different outcomes in a random variable.



Addressing risk in economic analysis

Sensitivity analysis is used to help understand how our decision might be affected if our original estimates are incorrect.

Sensitivity analysis determines different values of an independent variable affect a particular dependent variable under a given set of assumptions. It is also known as a what-if **analysis**



Example: Zinc-Lead-Silver mining project

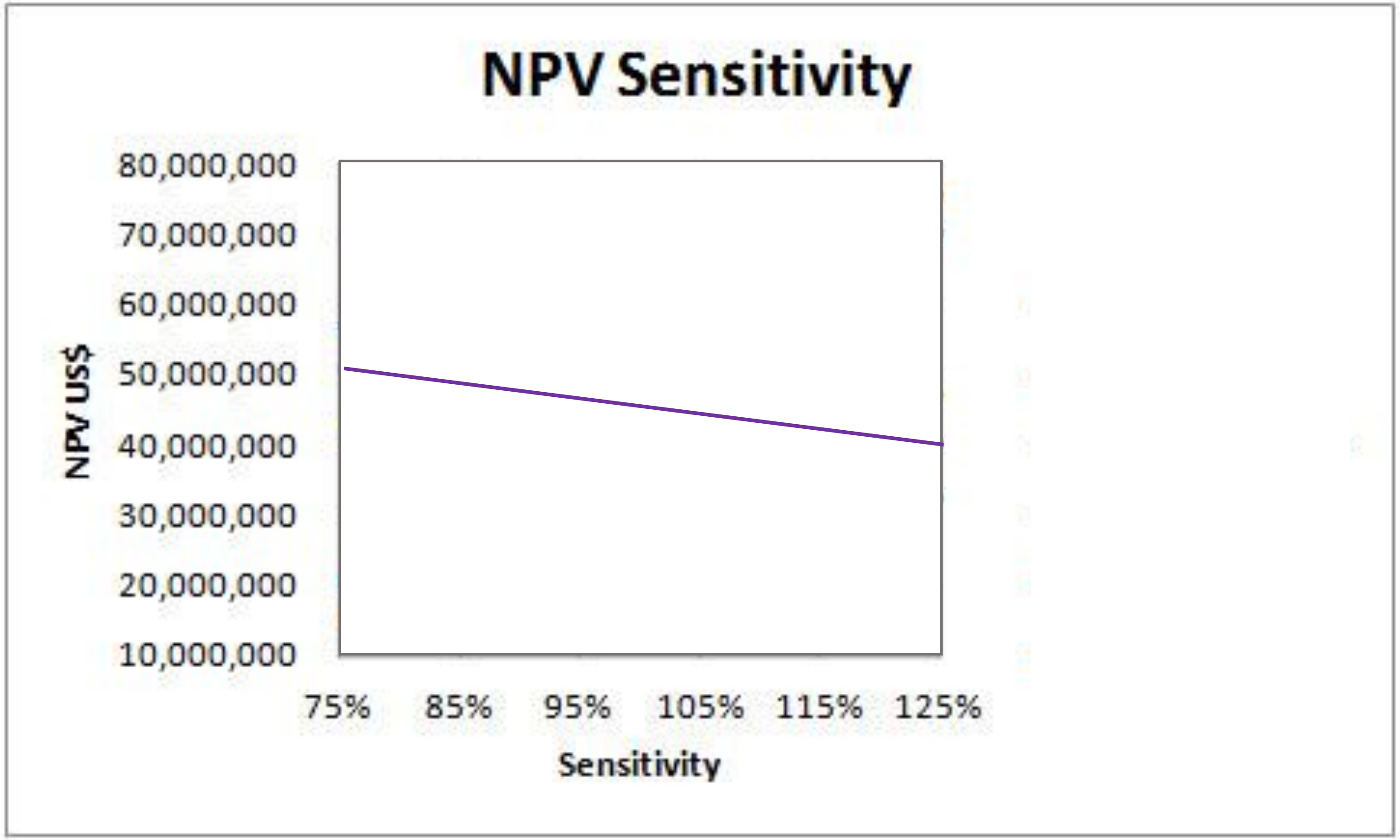
NPV with the 100% of estimated capital cost: 45.4 million

NPV sensitivity

% capital cost base case value	NPVs in US$
75%	500000000
85%	490000000
95%	480000000
105%	440000000
115%	410000000
125%	390000000

- **Economic Assessment for the Torlon Hill Zinc-Lead-Silver Deposit, Guatemala**

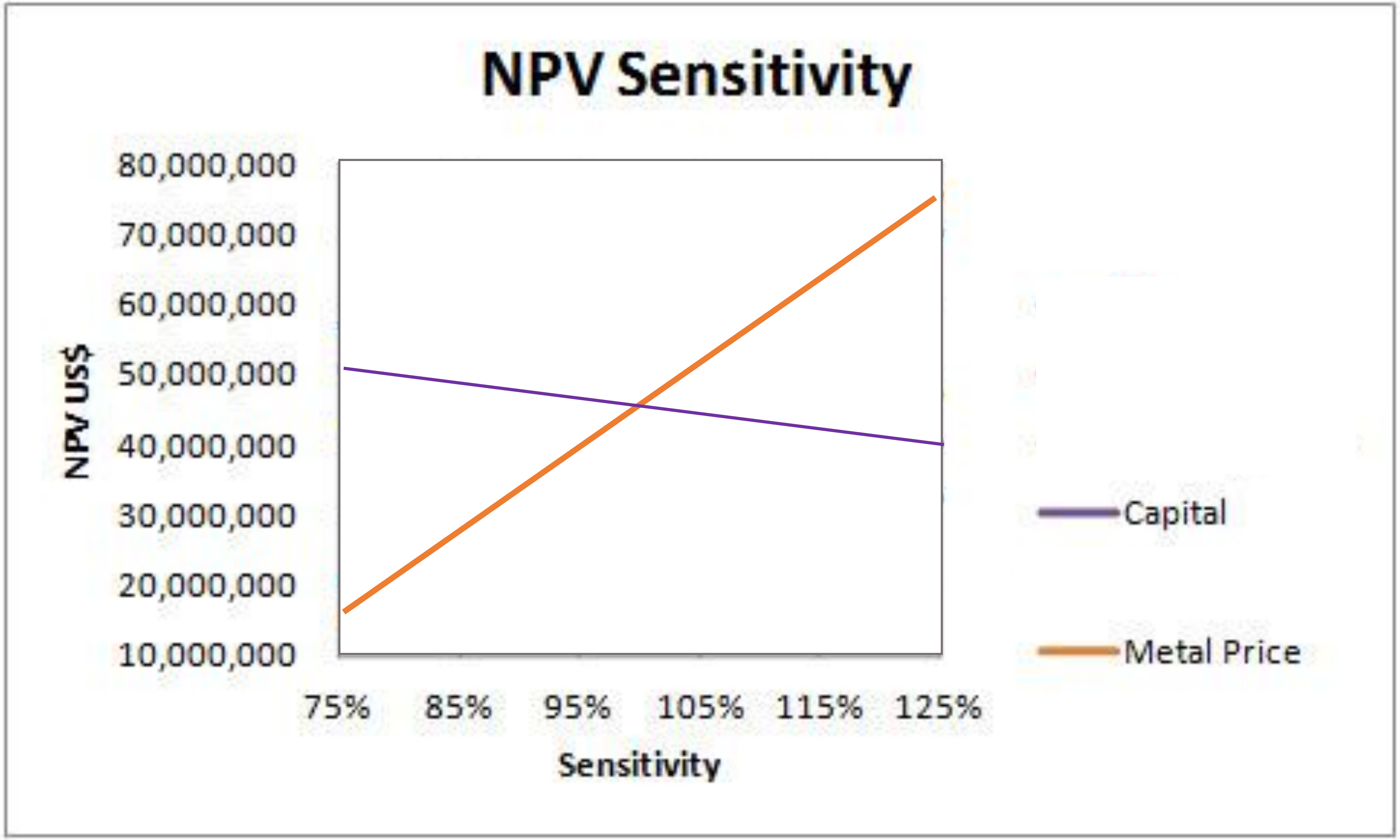
NPV sensitivity



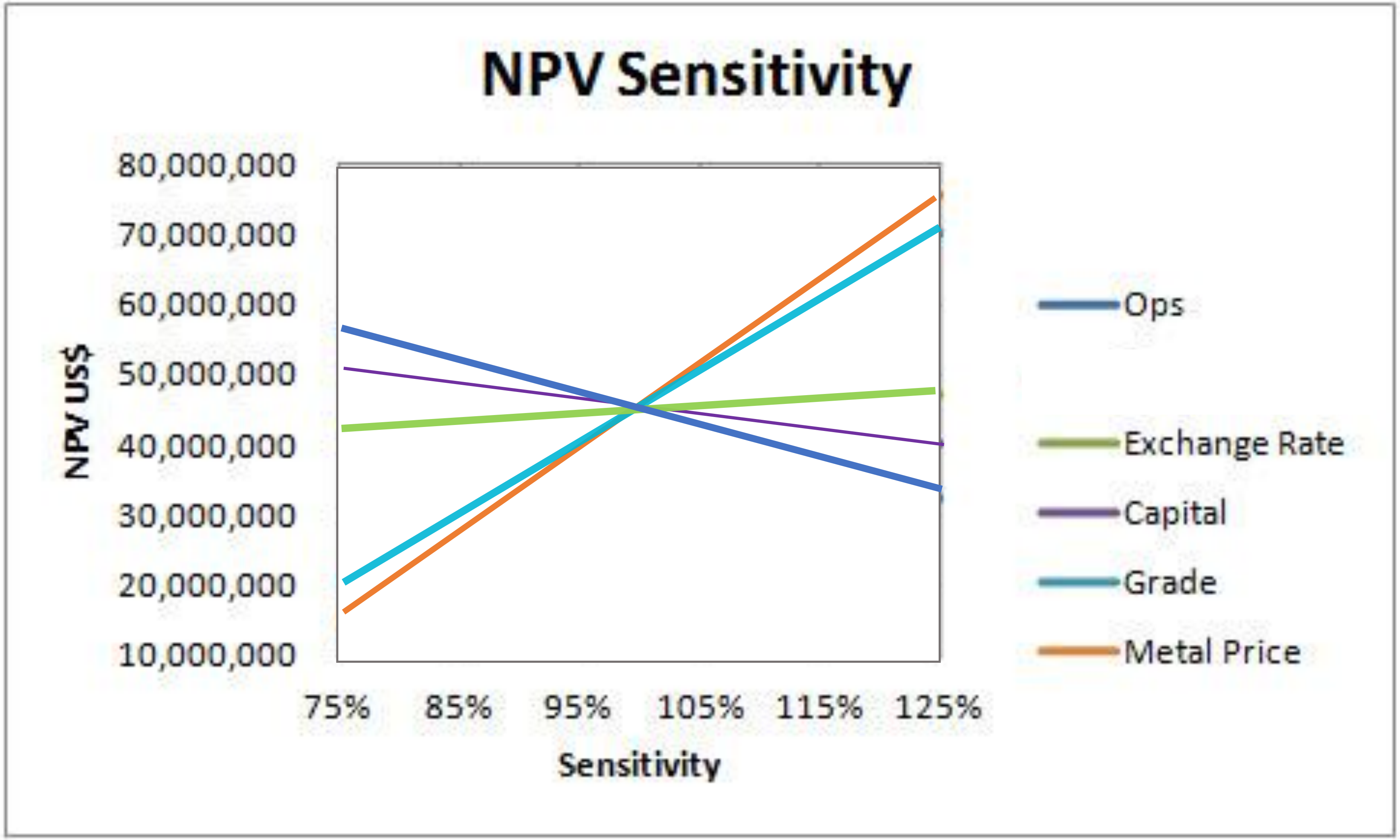
NPV sensitivity

% of Metal price base case value	NPVs in US$
75%	160000000
85%	270000000
95%	400000000
105%	520000000
115%	640000000
125%	760000000

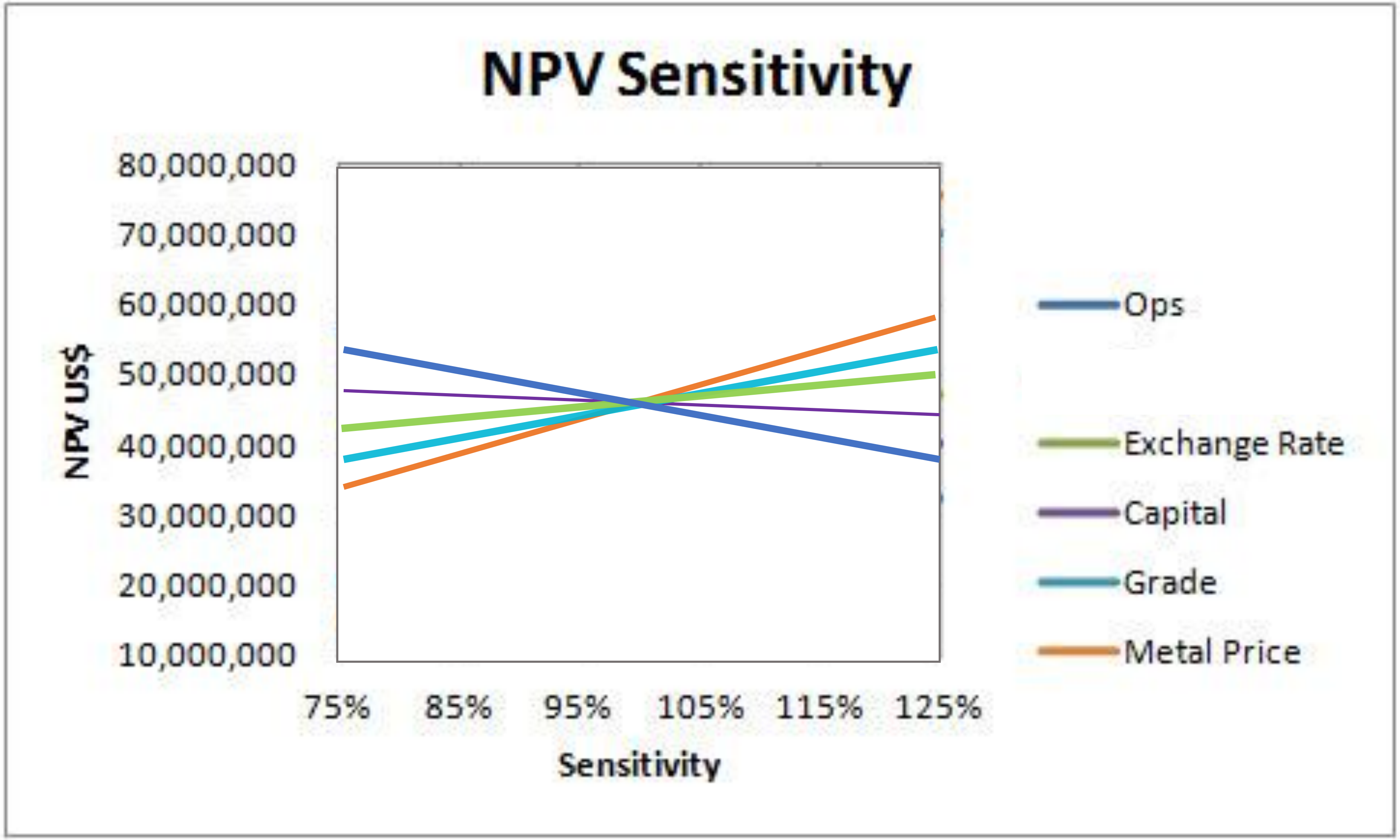
NPV sensitivity



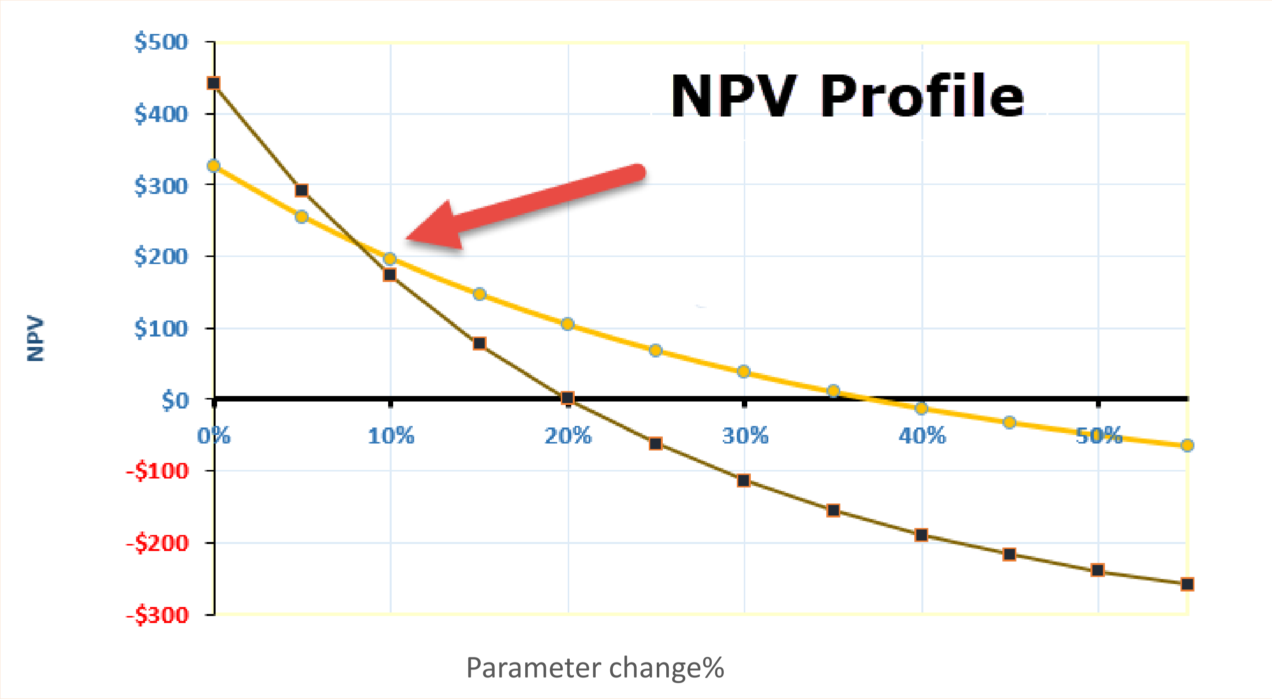
NPV sensitivity-Project A



NPV sensitivity-Project B



NPV sensitivity



Learning Activity

- Acme Delivery is considering a proposal for new package tracking technology. The system has an Estimated initial cost of $1.9 million and will require maintenance of Estimated $140,000 each year. Acme estimates that improved tracking will save approximately $680,000 per year, after system operating expenses. Consider a 6 years study period.
- Determine how sensitive the decision to invest in the system is to the estimates of initial investment and maintenance cost, annual savings.

Weaknesses of sensitivity analysis

- Only shows the impact of changes on one variable at a time
- It does not show how far the variable might change
- It does not address the probability of different values of variable’s change
- It does not address the impact of correlation between variable on the result
- Static Analysis: May not account for changes over time or in different scenarios, leading to misleading results.

Probability concepts in economic analysis

Relative Frequency Distribution

- A frequency distribution makes it easy to see exactly how many observations are in each category. Sometimes we are interested in the proportion of observations in each category.
- The proportion of observations in a category is called the **relative frequency** of the category.
- A **relative frequency distribution** is a table that presents the relative frequency for each category

Computing Relative Frequencies

The relative frequency of a category is the frequency of the category divided by the sum of all the frequencies.

$$\text{Relative Frequency} = \frac{\text{Frequency}}{\text{Sum of all frequencies}}$$

Bar Graphs

- A **bar graph** is a graphical representation of a frequency distribution.
- A bar graph consists of rectangles of equal width, with one rectangle for each category.
- The heights of the rectangles represent the frequencies or relative frequencies of the categories.

Frequency Distribution & Classes

To summarize quantitative data, we use a **frequency distribution** just like those for qualitative data. However, since these data have no natural categories, we divide the data into classes.

Class	Frequency
0 – 4	2
5 – 9	4
10 – 14	9
15 – 19	3

Classes are intervals of equal width that cover all values that are observed in the data set.

Classes

The **lower class limit** of a class is the smallest value that can appear in that class.

The **upper class limit** of a class is the largest value that can appear in that class.

The **class width** is the difference between consecutive lower class limits.

Lower Class Limits

Upper Class Limits

Class	Frequency
0 – 4	2
5 – 9	4
10 – 14	9
15 – 19	3

Class Width = 15 – 10 = 5

Constructing a Frequency Distribution

Following are the general steps for constructing a frequency distribution:

Step 1: Choose a class width.

Step 2: Choose a lower class limit for the first class. This should be a convenient number that is slightly less than the minimum data value.

Step 3: Compute the lower limit for the second class, by adding the class width to the lower limit for the first class:

Lower limit for second class = Lower limit for first class + Class width

Step 4: Compute the lower limits for each of the remaining classes, by adding the class width to the lower limit of the preceding class. Stop when the largest data value is included in a class.

Step 5: Count the number of observations in each class, and construct the frequency distribution.

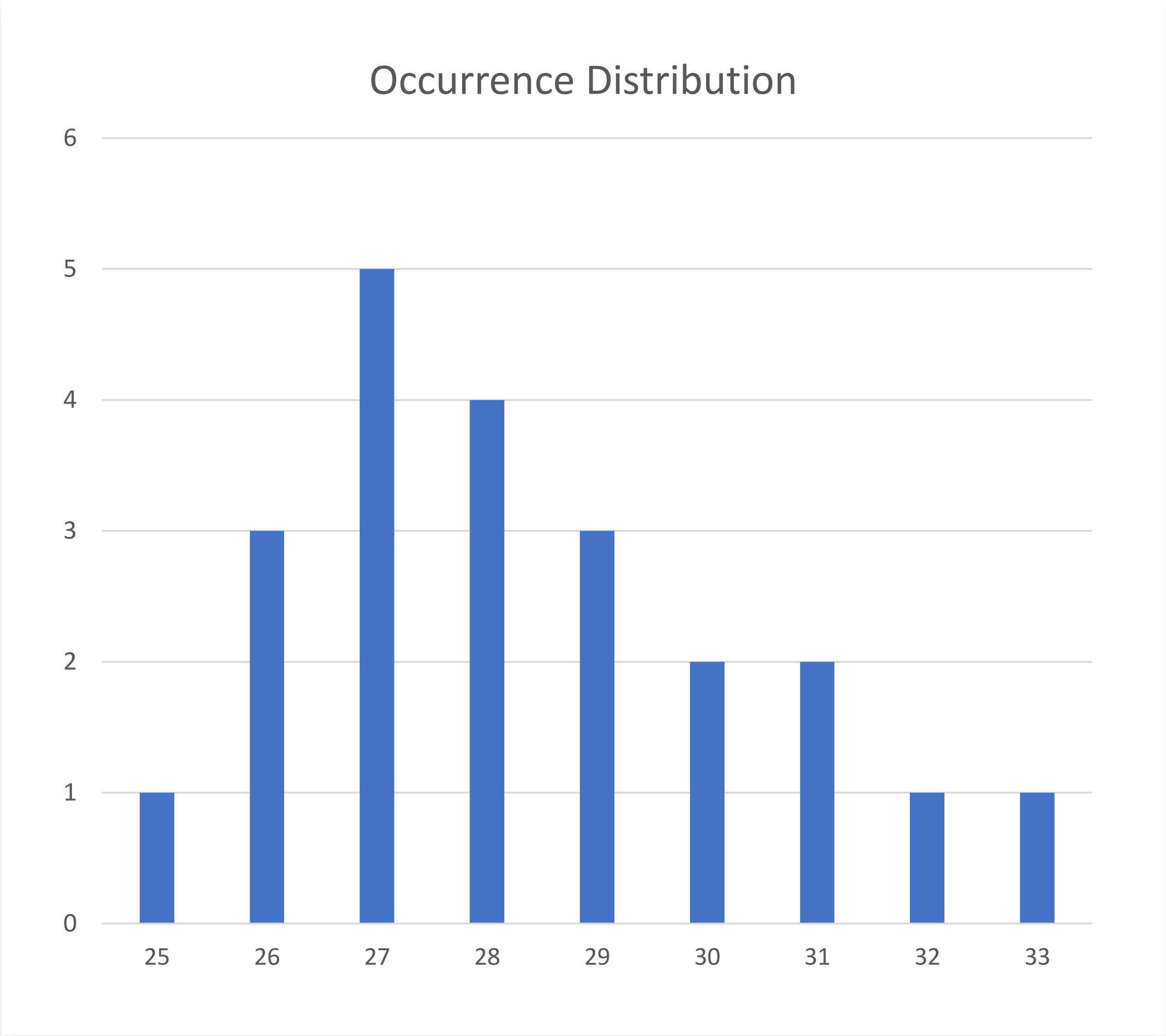
Discrete Probability distribution

Example: Zinc-Lead-Silver mining project

Estimated capital cost: 26 US$

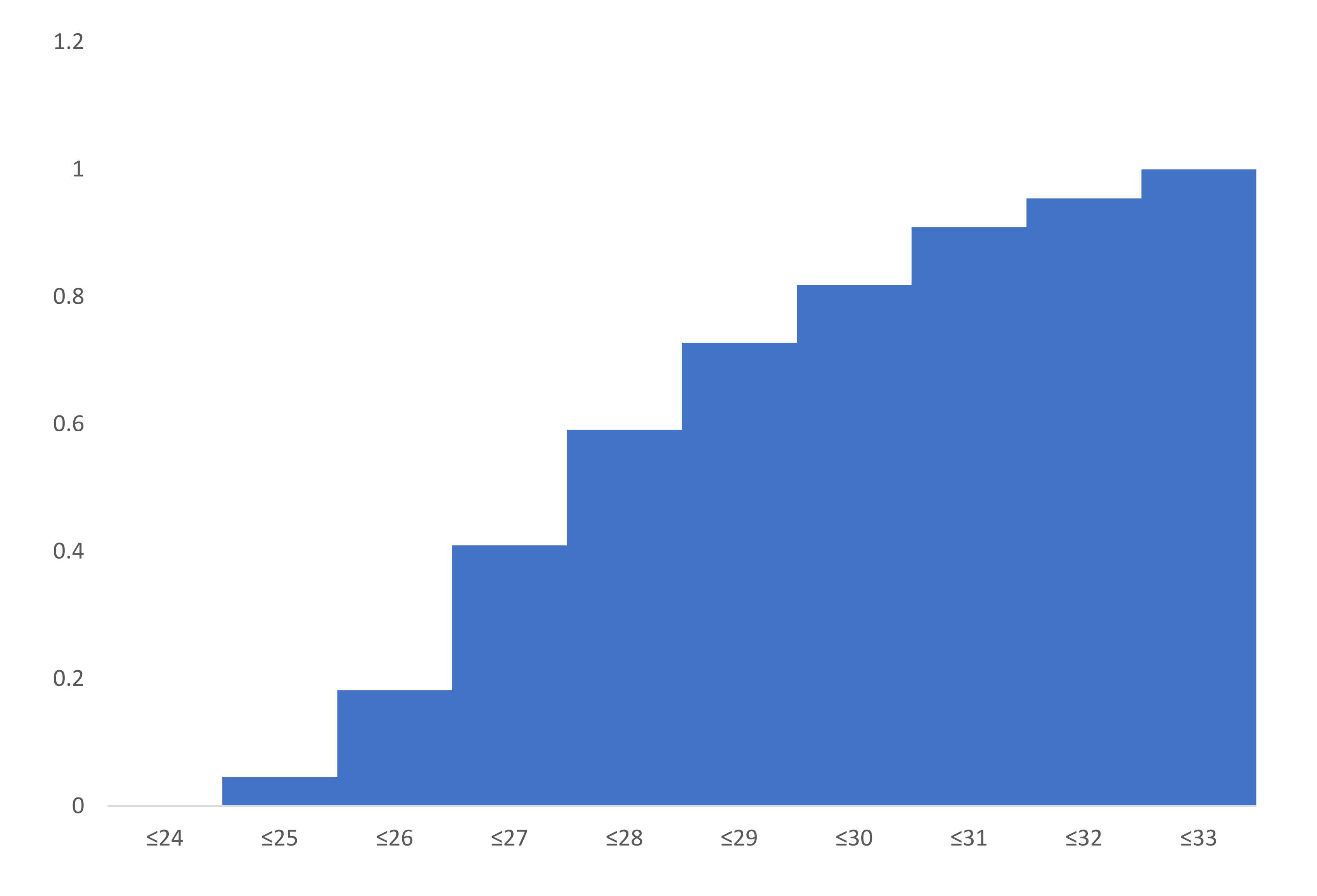
25	1	1/22	0.04
26	3	3/22	0.13
27	5	5/22	0.22
28	4	4/22	0.18
29	3	3/22	0.13
30	2	2/22	0.09
31	2	2/22	0.09
32	1	1/22	0.04
33	1	1/22	0.04

Discrete Probability distribution



Cumulative probability distribution function

Value	Occurance	Frequency of occurrence	Probability	Cumulative probability
≤24	0	0		0
≤25	1	1/22	0.045	0+0.045=0.045
≤26	3	3/22	0.135	0.045+0.135=0.18
≤27	5	5/22	0.22	0.40
≤28	4	4/22	0.18	0.59
≤29	3	3/22	0.13	0.72
≤30	2	2/22	0.09	0.81
≤31	2	2/22	0.09	0.90
≤32	1	1/22	0.04	0.95
≤33	1	1/22	0.04	1



Cumulative probability distribution function

Random variable

- **Random Variables:**
- A random variable is a numerical outcome of a random phenomenon, representing uncertainty in financial metrics.

- A discrete random variable is a variable that can take on a countable number of distinct values.

- Can be finite (e.g., number of students in a class) or infinite (e.g., number of times a coin is flipped until a head appears).
- Factors Such as Revenues, Costs, Etc., Can Often Be Considered Random Variables

Random variable

- **For discrete random variables X, the probability X takes on any particular value xi is**

$$P_r\{X = x_i\} = p(x_i) \ for \ i = 1,2,...., L$$

$$p(x_i) \geq 0 \quad \text{and} \quad \sum_i p(x_i) = 1$$

Properties of Discrete Random Variables

- **For discrete random variables X, the probability X takes on any particular value xi is**

Probability mass function

$$P_r\{a \le X \le b\} = \sum_{i:a \le x_i \le b} p(x_i)$$

Cumulative distribution function

$$P_r\{X \le h\} = P(h) = \sum_{i:x_i \le h} p(x_i)$$

Expected Value (Mean, Central Moment), E(X), and Variance (Measure of Dispersion), V(X), of a Random Variable X, Are:

$$E(X) = \sum_i x_i p(x_i), \text{ for X discrete;}$$

$$\int_{-\infty}^{\infty} xf(x)dx, \text{ for x continous.}$$

$$V(X) = \{\sum_i x_i^2 p(x_i) - [E(X)]^2, \quad \text{for X discrete;}$$

$$\int_{-\infty}^{\infty} x^2 f(x)dx - [E(X)]^2, \quad \text{for X continuous.}$$

The Expected Value

Values	Probability	Probability*values
25	0.0454545	1.136363636
26	0.1363636	3.545454545
27	0.2272727	6.136363636
28	0.1818182	5.090909091
29	0.1363636	3.954545455
30	0.0909091	2.727272727
31	0.0909091	2.818181818
32	0.0454545	1.454545455
33	0.0454545	1.5
	Expected outcome	28.36363636

Expected Value (Mean, Central Moment), E(X), and Variance (Measure of Dispersion), V(X), of a Random Variable X, Are

$$E(X) = \sum_i x_i p(x_i), \text{ for X discrete;}$$

$$\int_{-\infty}^{\infty} x f(x) dx, \text{ for x continous.}$$

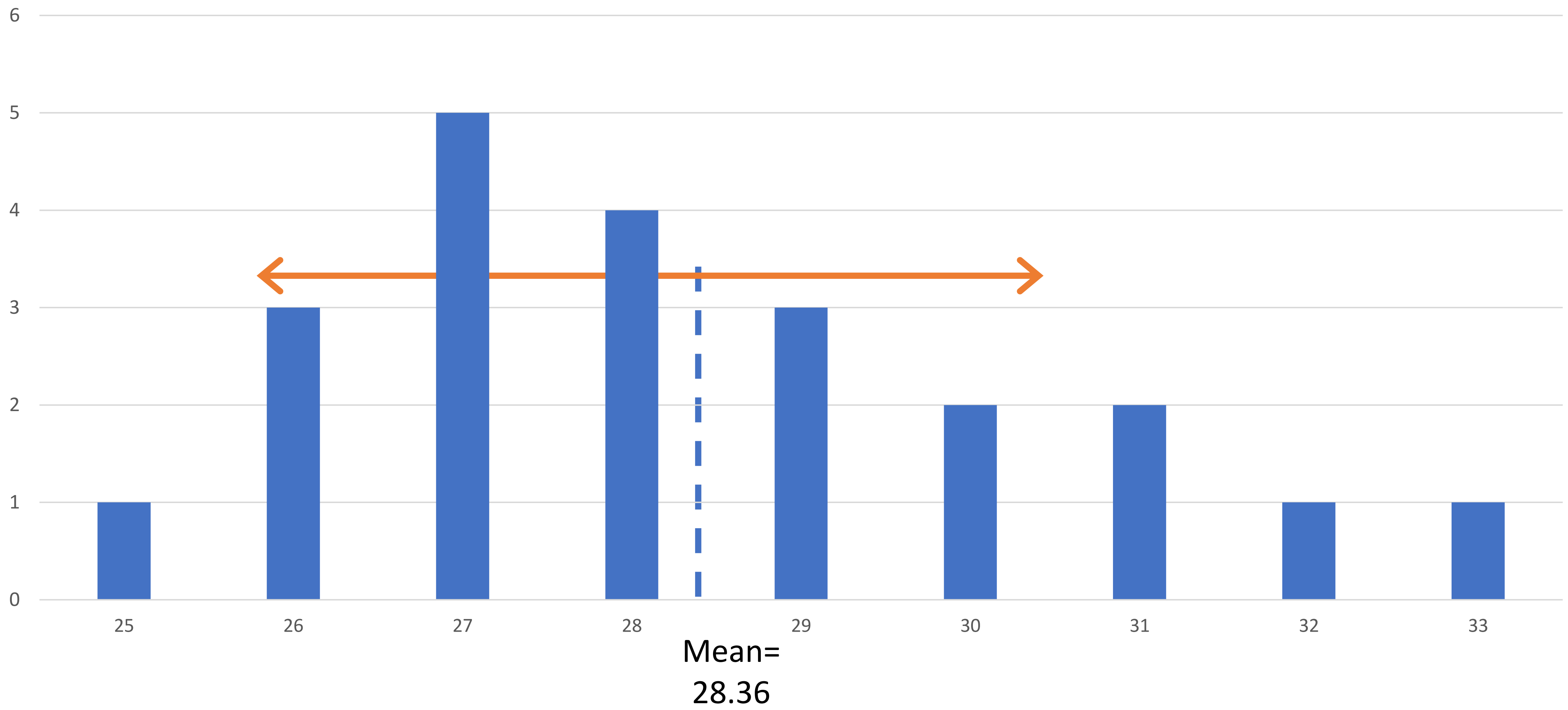
$$V(X) = \{\sum_i x_i^2 p(x_i) - [E(X)]^2, \quad \text{for X discrete;}$$

$$\int_{-\infty}^{\infty} x^2 f(x) dx - [E(X)]^2, \quad \text{for X continuous.}$$

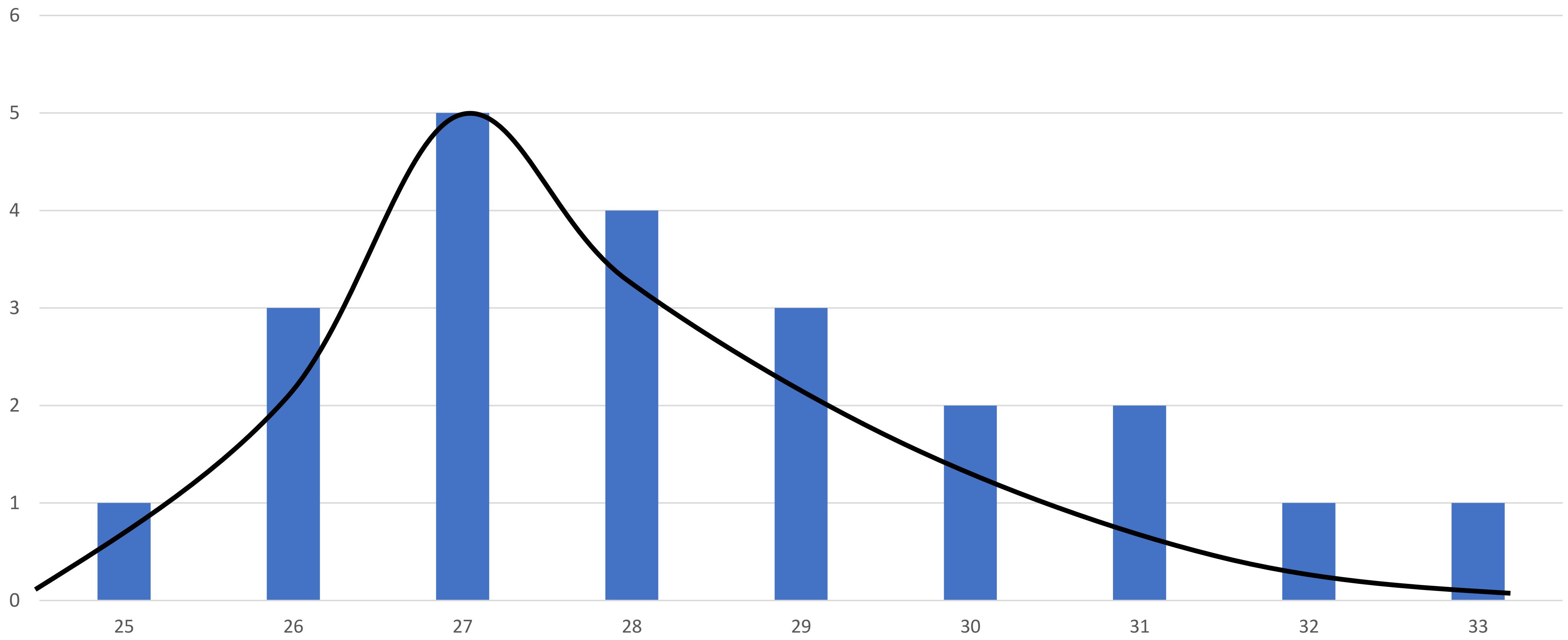
Expected Value (Mean, Central Moment), E(X), and Variance (Measure of Dispersion), V(X), of a Random Variable X, Are

Value	Probability	Value× Probability	Distance from the mean	Square of the distance	Square of the distance × Probability
25	0.045	1.136	-3.363	11.31404959	0.514274981
26	0.136	3.545	-2.363	5.58677686	0.761833208
27	0.22	6.13	-1.36	1.859504132	0.422614576
28	0.18	5.09	-0.36	0.132231405	0.024042074
29	0.136	3.954	0.636	0.404958678	0.055221638
30	0.09	2.73	1.63	2.67768595	0.243425995
31	0.09	2.82	2.63	6.950413223	0.631855748
32	0.045	1.454	3.636	13.2231405	0.601051841
33	0.045	1.5	4.636	21.49586777	0.977084899
	Weighted average	28.36		Variance	4.23
				Standard deviation	2.057

Expected Value (Mean, Central Moment), E(X), and Variance (Measure of Dispersion), V(X), of a Random Variable X, Are



Discrete probability distribution



Procedure for Finding the M

Arrange the data values in increasing order.

Determine the number of data values, n.

If n is odd, the median is the middle number.
median is the value in position $(n + 1)/2$.

If n is even, the median is the average c
numbers. That is, the median is the averag
positions $n/2$ and $n/2 + 1$.

Another value that is sometimes classified as a measure of center is the **mode**.

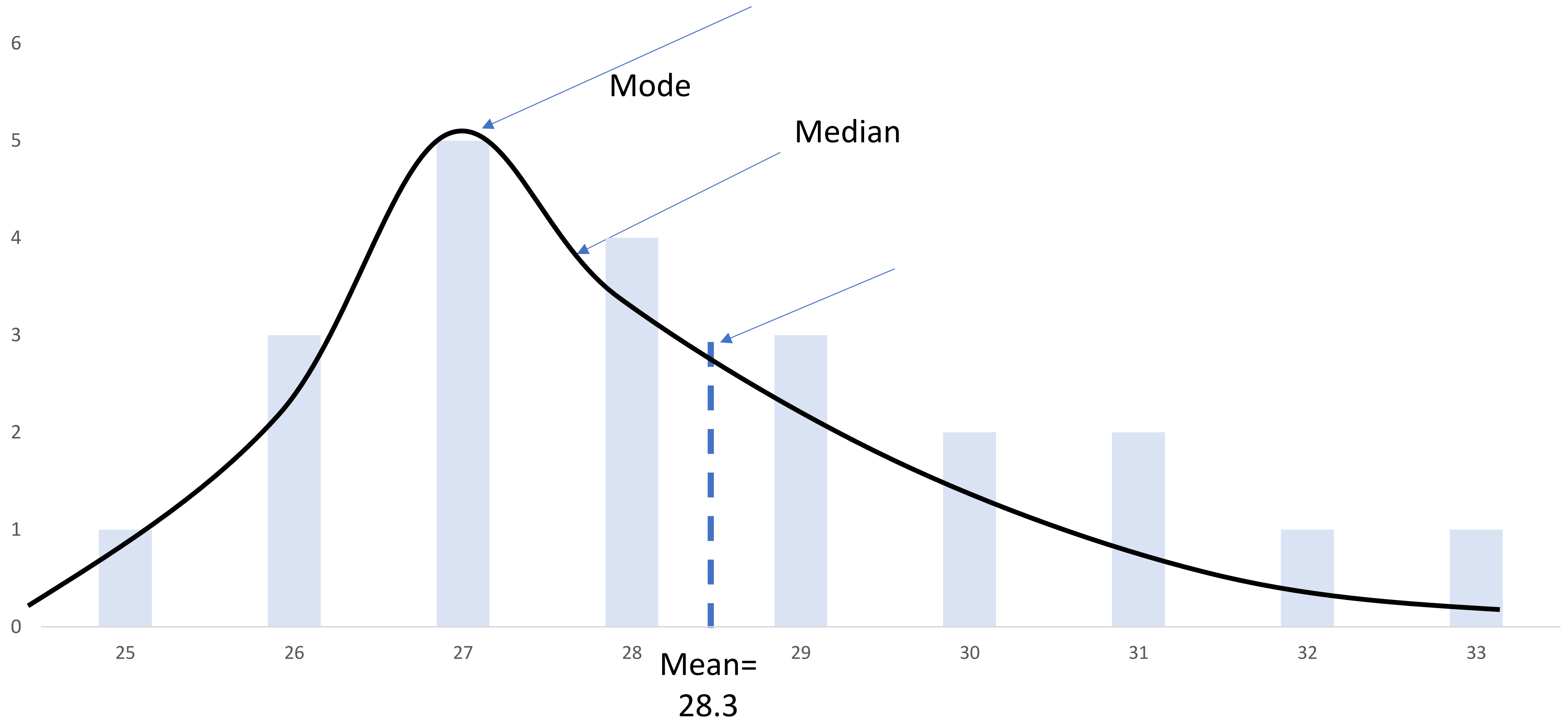
The mode of a data set is the value that appears most frequently.

If two or more values are tied for the most frequent, they are all considered to be modes.

If no value appears more than once, we say that the data set has no mode.

Mode and Median

- Mode: most likely
- P50: median



Learning Activity

Acme manufacturing has installed a much-needed new CNC machine

- The initial investment in this machine is $180,000 and annual expenses are $12,000. The life of the machine is expected to be 5 years, with a $20,000 market value at that time. **Possible revenues follow the probabilities given below.**
- What Are the Expected Value and Variance of Acme's Revenue?

Revenue	Probability
$35,000	0.1
$44,000	0.3
$50,000	0.4
$60,000	0.2

What Are the Expected Value and Variance of Acme's Revenue?

$$E(X) = \sum_i x_i p(x_i)$$

$$\begin{aligned} E(X) &= (35{,}000)(0.1) + (44{,}000)(0.3) \\ &= +(50{,}000)(0.4) + (60{,}000)(0.2) \\ &= \$48{,}700 \end{aligned}$$

Learning Activity – Metro Transport Planning

- MetroLogix is considering a smart ticketing system upgrade.
- Initial investment: $120,000 | Maintenance: $10,000/year | Life: 5 years
- Annual savings: $42,000
- Revenue projections due to improved efficiency with their probability:
- $25,000 (probability: 0.2), $30,000 (probability: 0.4), $35,000 (probability: 0.3), $45,000 (0.1)

- Tasks:
- 1. Calculate expected annual revenue.
- 2. Estimate variance and standard deviation.
- 3. Discuss implications for investment decision.