Example [MET]

- A metal processing company is renovating the heat treatment line.
- Current process (as-is)
- After heat treatment, material is subject to cooling process, which is performed by means of continuous supply of industrial water (*once-through cooling*) without any recycle/reuse.
- Since the cooling water does not come into contact with contaminants, it is discharged to municipal sewerage system without treatment.

Example [MET]

- Future process (to-be)
- In order to make the process cleaner, cooling will be performed by *internal closed loop* cooling cycles.
- The main outcome is a substantial reduction in freshwater consumption and wastewater generation in the heat-treatment process.
- The new layout configuration and water recirculation system saves 24,200m^3 per year of water input.
- Compared to the current setup, the revised configuration will require one fewer 4kW submersible pump.
- This implies a reduction of 7,800kWh of electric energy per year.

Example [MET]

- In a first *base assessment*, the values of the parameters are considered constant.
- Economic data
  - average cost of industrial water: 0.65 €/m^3
  - cost of electric energy: 0.24 €/kWh

- Considering the quantities saved, we have:

Cost saving (water)	15730	€/yr
Electricity savings	1872	€/yr
Total annual savings	**17602**	**€/yr**

Example [MET]

- The investment outlay for the new system is 34,000€ including
  - water storage tank
  - piping (needed pumps will be sourced from the existing system)
  - electrical and control system
  - disassembling, assembling and other costs.
- Differential operating costs (€/yr) associated with the new system:

Planned maintenance	3400
Water treatment (consumables)	1000
Monitoring and Control	1700
O&M Costs	**6100**

Example [MET]

- The MET company assigns a five-year useful life to the asset, without salvage value.
- MARR is obtained as:

$$MARR(\%) = rf + pi + pp = 3.2 + 4.5 + 1.0 = 8.7\%$$

- The estimated inflation rate is 2.5%.
- The real MARR is then 6%.

Example [MET]

- The cash flows in the comparison “to-be” vs “as-is” are:

Net savings per year (€)	11502
Present value of savings (€)	48450.61
Net Present Value (€)	**14450.61**

- The IRR is about 0.21.

Example [MET]

- After deeper investigation, MET updated some features and performed an *extended assessment*:
  - unit cost of water is expected to increase to 0.68€/m^3 in years 3-5
  - unit cost of electric energy is expected to increase to 0.26€/kWh in years 2-3 and to 0.28€/kWh in years 4-5
  - operations and maintenance costs are expected to increase to 6500€/yr in years 3-4 and to 7000€/yr in year 5.

Example [MET]

- The updated profile of the cash flows is:

	Base	0	1	2	3	4	5
Water saved (m3/yr)	24200		24200	24200	24200	24200	24200
El. en. saved (kWh/yr)	7800		7800	7800	7800	7800	7800
Unit cost of ind. water (€/m3)	0.65	0.65	0.65	0.65	0.68	0.68	0.68
Unit cost of El. en. (€/kWh)	0.24	0.24	0.24	0.26	0.26	0.28	0.28
Investment outlay	34000	34000					
Oper. Maint. cost (€/yr)	6100		6100	6100	6500	6500	7000
Total savings (€/yr)	17602		17602	17758	18484	18640	18640
Free cash flow (€/yr)		-34000	11502	11658	11984	12140	11640

- The NPV can be obtained by discounting (at real MARR=6%) and adding the free cash flows; NPV = 15,602.6€

Effects of uncertainty

- The evaluation of a project is performed before the implementation.
- The determination of values is therefore based on forecasts and affected by uncertainty.
- The calculation of economic performance indicators should therefore be accompanied by a study that analyses the effect of uncertainty on their value.

- The study can be elaborated performing:
  - a sensitivity analysis
  - a risk analysis
  - a scenario analysis.
- The purpose of these analyses is:
  - identify the most uncertain elements
  - assess their effect on the indicator.

Uncertainty

- It refers to a situation in which several aspects of the evaluation or decision are not deterministically known.
- Examples of parameters: the quantity of the energy demanded by users or the unit cost of natural gas in a certain year.
- Under the condition of uncertainty, no information is available regarding the probability of a certain state or event.

Risk

- In this case, information on the probability of events or states of the system can be determined.
- This information can be derived from an *objective* (e.g. frequentist) or *subjective* probability assessment.

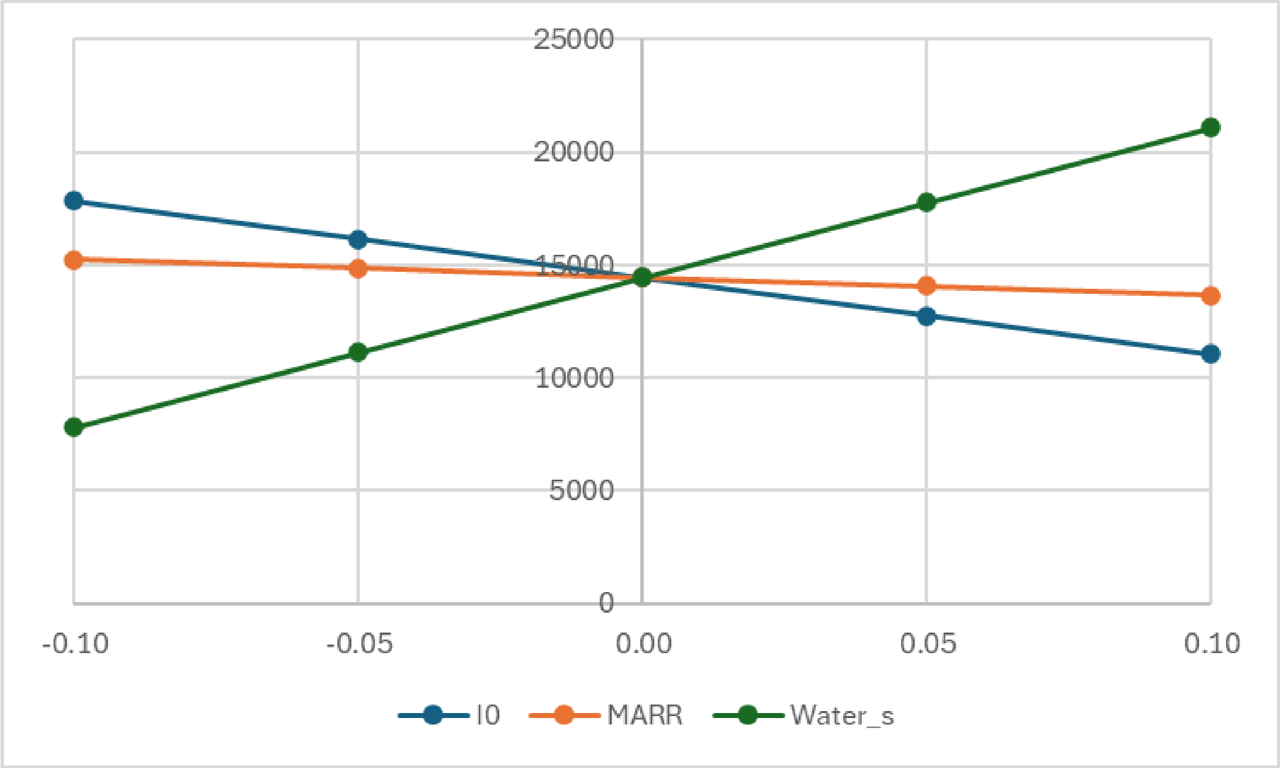
Sensitivity analysis

- The typical steps of sensitivity analysis are:
  - identification of variables used in the model of the economic indicator (e.g. NPV) which have significant levels of uncertainty
  - determination of a plausible range of variation for each variable identified in the previous step
  - analysis of economic performance indicators at values in the range
  - identification of critical thresholds, beyond which the investment is no longer profitable.

Example [MET]

- In the MET example (base assessment) three variables were identified as being affected by uncertainty:
  - investment cost
  - MARR
  - water saved per year.
- The range of variation was set between +10% and -10%.

- A *spider diagram* representing the NPV was thus constructed; it enables the identification of the variables which have the greatest impact on NPV:



The steeper slope shows that the effect on the NPV of the quantity of saved water is stronger than the effect of I0 and MARR.

- For the execution of sensitivity analysis with Excel, we can use

  Data > What-If Analysis > Data table

- *Example*:

30000	
32000	
34000	
38000	
40000	

- in the first column, enter the values of the studied variable (e.g. the investment cost I0)

- For the execution of sensitivity analysis with Excel, we can use

Data > What-If Analysis > Data table

- *Example*:

	15602.62
30000	
32000	
34000	
38000	
40000	

- in the first column, enter the values of the studied variable (e.g. the investment cost I0)
- the value at the top of the second is placed equal to the cell where the index is calculated (in this example, the NPV); the cells below that are currently empty
- all cells in the two columns are selected

- the Data Table command is applied with “Input cell by column” in which the reference to the cell containing the variable used in the index calculation is entered

- For the execution of sensitivity analysis with Excel, we can use

  Data > What-If Analysis > Data Table

- *Example*:

I0	15602.62
30000	17602.62
32000	16602.62
34000	15602.62
38000	13602.62
40000	11602.62

- in the first column, enter the values of the studied variable (e.g. the investment cost I0)
- the value at the top of the second is placed equal to the cell where the index is calculated (in this example, the NPV); the cells below that are currently empty
- all cells in the two columns are selected

- the Data Table command is applied with “Input cell by column” in which the reference to the cell containing the variable used in the index calculation is entered
- values are calculated and entered by Excel.

- Sensitivity analysis is typically performed considering the variation of only one variable at a time.
- The most frequently used variables are:
  - discount rate or MARR
  - prices or quantities of inputs
  - prices or quantities of outputs
  - salvage value.

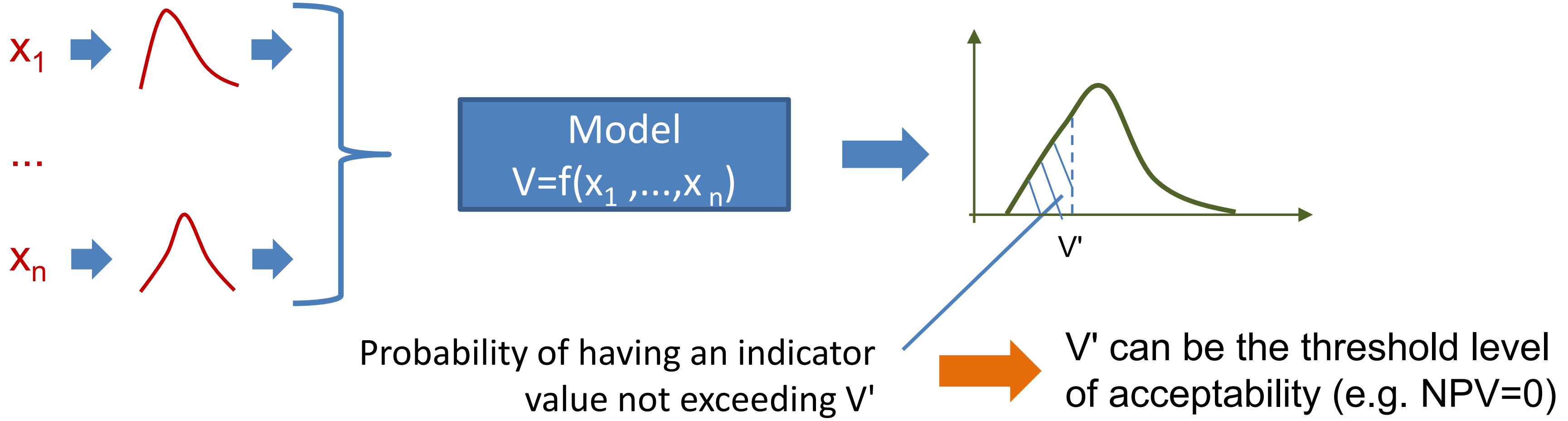
Risk analysis

- It is more complex than the previous one, as it requires estimating, in the simplest case, two components:
  - the probability of a possible event (P_i)
  - the impact of this event on the result (E_i).
- The risk can then be obtained from the product

$$R_i = P_i \cdot E_i$$

- The risk of an event can be significant if both the probability and impact are not negligible.

- Given a variable (x) affected by uncertainty, it is possible to estimate the probability distribution of its values.
- For each value, the effect on the indicator is calculated.
- This procedure can be performed with a *simulation model* that outputs the values (V) of the indicator:



- This approach often uses Monte Carlo simulation methods.
- Regardless of the tools used, it is still a matter of defining the distributions of the variables.
- The simulation can take several variables into account simultaneously.
- A pragmatic approach:
  - perform sensitivity analysis to determine the most significant x variables
  - identify the plausible range of variation for each x
  - identify the probability distribution for these values
  - remove possible incompatible conditions (between different x values)
  - execute the simulation.

Example [MET]

- After the base assessment, the company performs a simulation analysis regarding the new closed-loop cooling system.
- The table in the next slide shows the stochastic variables employed in the model:
  - water saved in a year (Normal probability distribution)
  - unit cost of industrial water (Uniform probability distribution)
  - unit cost of electric energy (Uniform probability distribution)
  - MARR (Uniform probability distribution)
  - investment cost (Normal probability distribution)

- Parameters of the probability distributions:
  - Normal: mean, standard deviation
  - Uniform: minimum value, maximum value
- O&M cost is estimated at 18% of the investment cost.

Water saved per year		NORMAL	24200	3000
Electric energy saved per year	7800			
Average cost of industrial water		UNIFORM	0.55	0.75
Cost of Electric energy		UNIFORM	0.2	0.3
MARR		UNIFORM	0.05	0.08
Investment cost		NORMAL	34000	5000

- Excel allows simulation experiments to be produced by means of:
  - generation of (pseudo-)random numbers
  - use of probability distributions
  - calculation of summary statistical indicators.
- In practice, we can set up a row (or column) in which the calculation formulae, containing stochastic variables, are displayed.
- Each instance of the experiment generates a set of random numbers used in the formulas.
- If N rows (or columns) are used, there will be N experiments.

- In Example [MET], each experiment is in a column.

	1
Water saved per year	29244.7
Electric energy saved per year	7800
Cost of industrial water	0.66
Cost of Electric energy	0.23
MARR	0.07
Investment cost	33369.7
O&M Cost	6006.5
Cost saving (water)	19443.5
Electricity savings	1757.5
Total savings per year	21201.0
Net savings per year (€)	15194.5
NPV	**29654.5**

- Examples of used formulas:
  - Water saved per year: NORM.INV(RAND();mean;std_dev)
  - Cost of industrial water: min_cost+(max_cost – min_cost)*RAND()
- Examples (in Italian):
  - Water saved per year: INV.NORM.N(CASUALE();mean;std_dev)
  - Cost of industrial water: min_cost+(max_cost – min_cost)*CASUALE()

- In Example [MET], N=200 test columns were set.
- The summary measures taking into account the simulation results were then set up:

NPV average	14458.77
NPV sd	13762.57
NPV min	-19376.2
NPV max	47169.13
Events with negative NPV	31
Incidence of negative NPVs	15.5%

- There is a 15.5% of experiments where the NPV is negative.
- Attention: when a worksheet is recalculated (by entering a formula or data in a different cell) or by pressing F9 (manual recalculation), a new random number is generated for any formula using the RAND() function.

Scenario analysis

- A check on the stability of the indicator value, obtained by calculation under “basic” conditions, can be made by changing the values of the key variables.
- Several alternative scenarios characterised by *mutually compatible* values of the critical variables are constructed.
- For each scenario, the calculation are in practice performed under deterministic conditions.
- Scenarios are often an expression of different conditions under which the project might take place:
  - basic (current) scenario
  - pessimistic scenarios (e.g. low demand and high investment cost)
  - optimistic scenarios (e.g. high demand and low investment cost).

- In the Example [MET] (extended assessment) the following scenarios were identified:
  - “worst” (pessimistic): a smaller quantity of water than in the basic scenario is saved each year; the unit cost of industrial water is lower, the investment cost is higher
  - “best” (optimistic): a larger quantity of water than in the basic scenario is saved each year; the unit cost of industrial water is higher, the investment cost is lower
  - “intermediate”: even if the investment cost is the same of the “worst” scenario, the unit cost of water is the same as in the basic scenario and the water saved yearly is the same of the “best” scenario.
- It was verified that each scenario is actually possible.

- Using Excel's "Scenario Manager" tool (Data > What-If Analysis > Scenario Manager), we obtain (Scenario Summary):

		Current values:	Worst	Best	Intermediate
Variable cells:					
	S_w_sav	24200	21000	26000	26000
	S_Cost_w	0.65	0.6	0.68	0.65
	S_Inv	34000	38000	32000	38000
Result cells:					
	S_NPV	15746.5	-1810.5	26192.6	16814.2

- The project is not robust enough to ensure positive profitability in the "worst" (pessimistic) scenario.