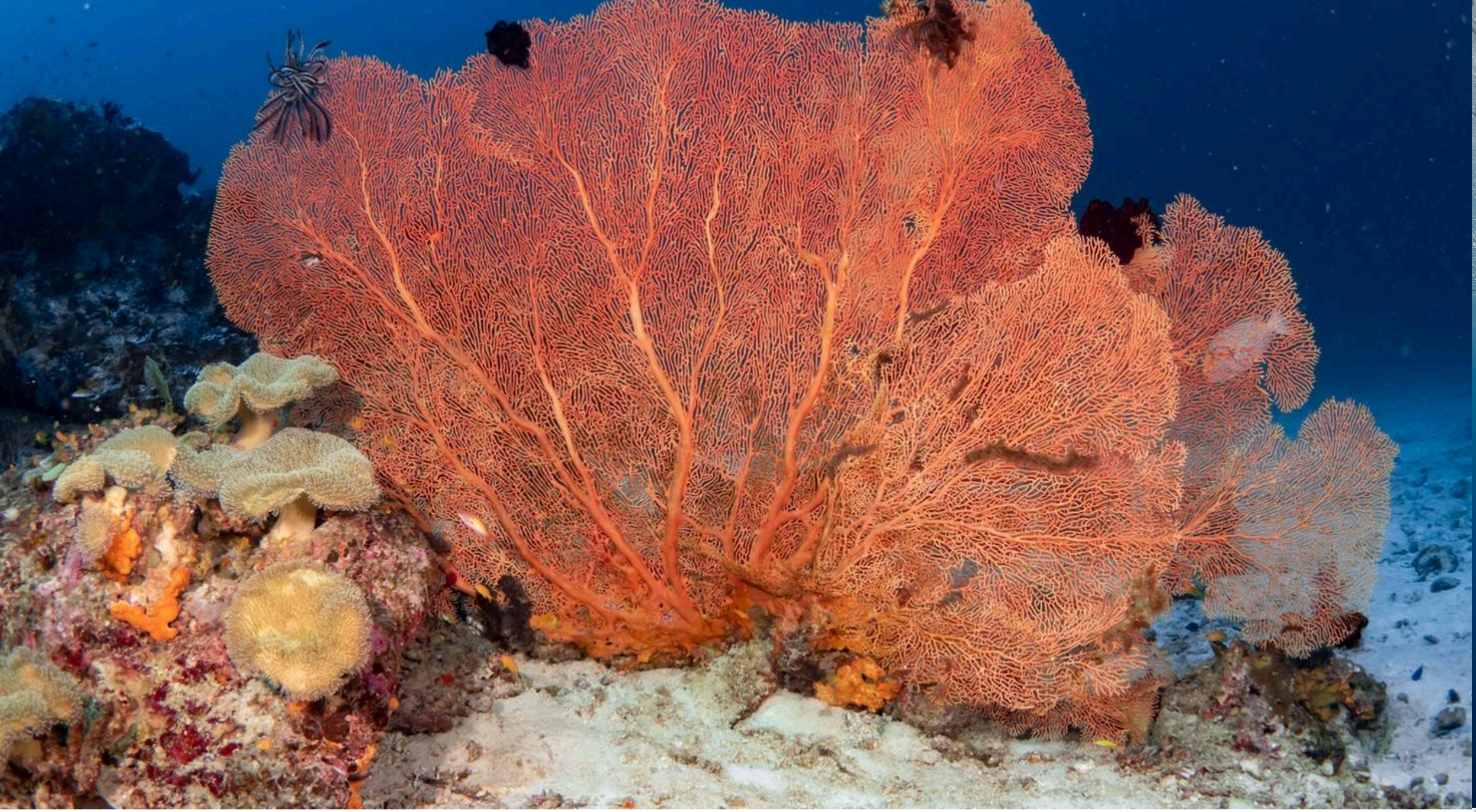
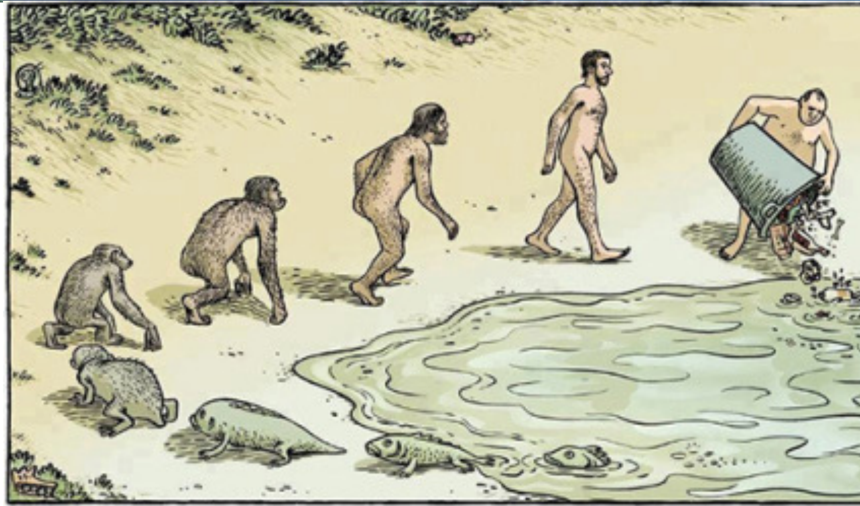




EE476
Environmental Economics

Lecture 9

2022

Discount factors

(PV of value of $1 in year t with r%)

Years	1%	2%	5%	10%
1	0.9901	0.9804	0.9524	0.9091
2	0.9803	0.9612	0.9070	0.8264
5	0.9515	0.9057	0.7835	0.6209
10	0.9053	0.8203	0.6139	0.3855
20	0.8195	0.6730	0.3769	0.1486
50	0.6080	0.3715	0.0872	0.0085
…	…	…	…	…
100	0.36971	0.13803	0.0076	0.0001

Investment criteria : Net Present Value: NPV

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

where B_t = Benefits in year t

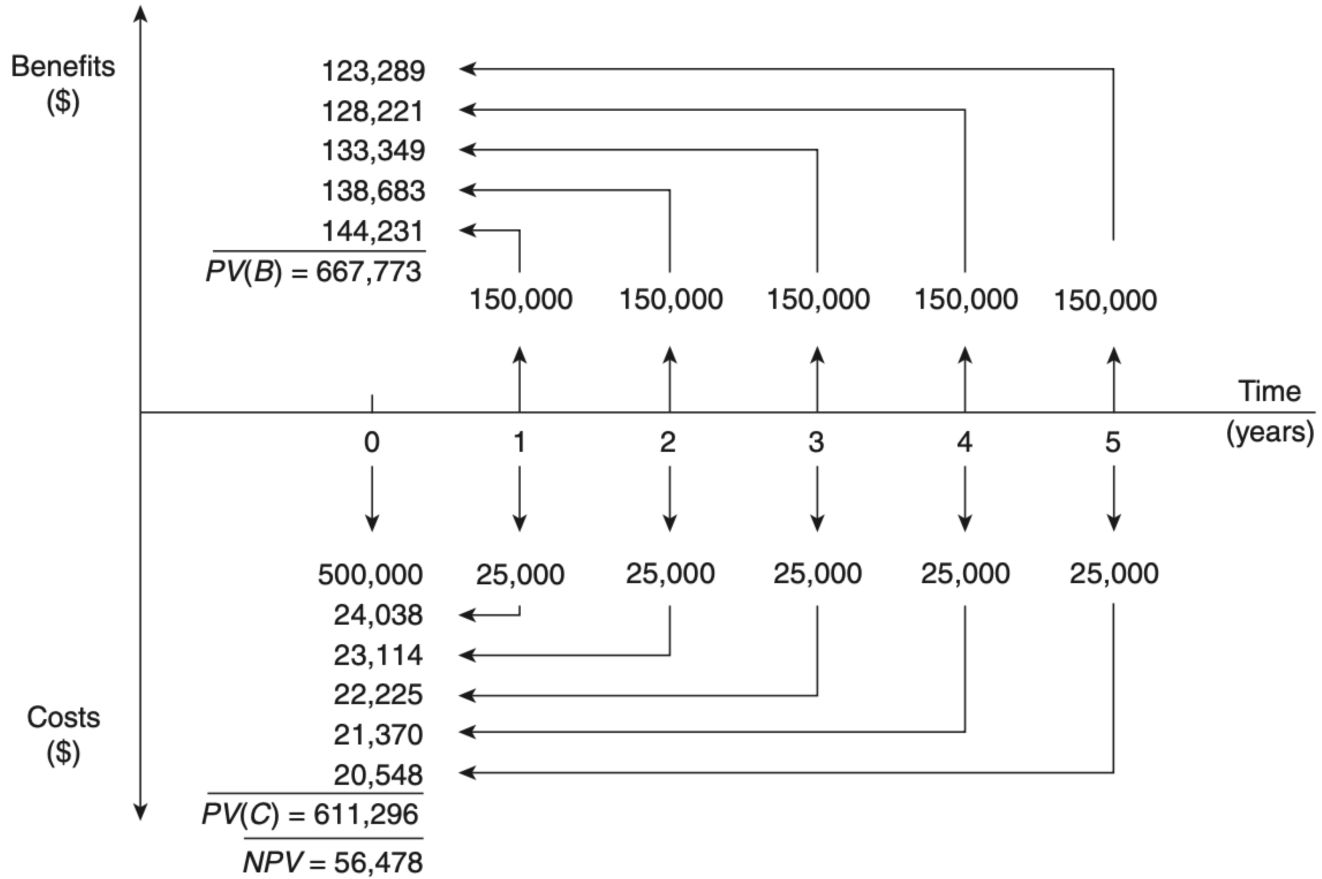
C_t = Cost in year t

r = discount rate

NPV > 0 ➔ Invest

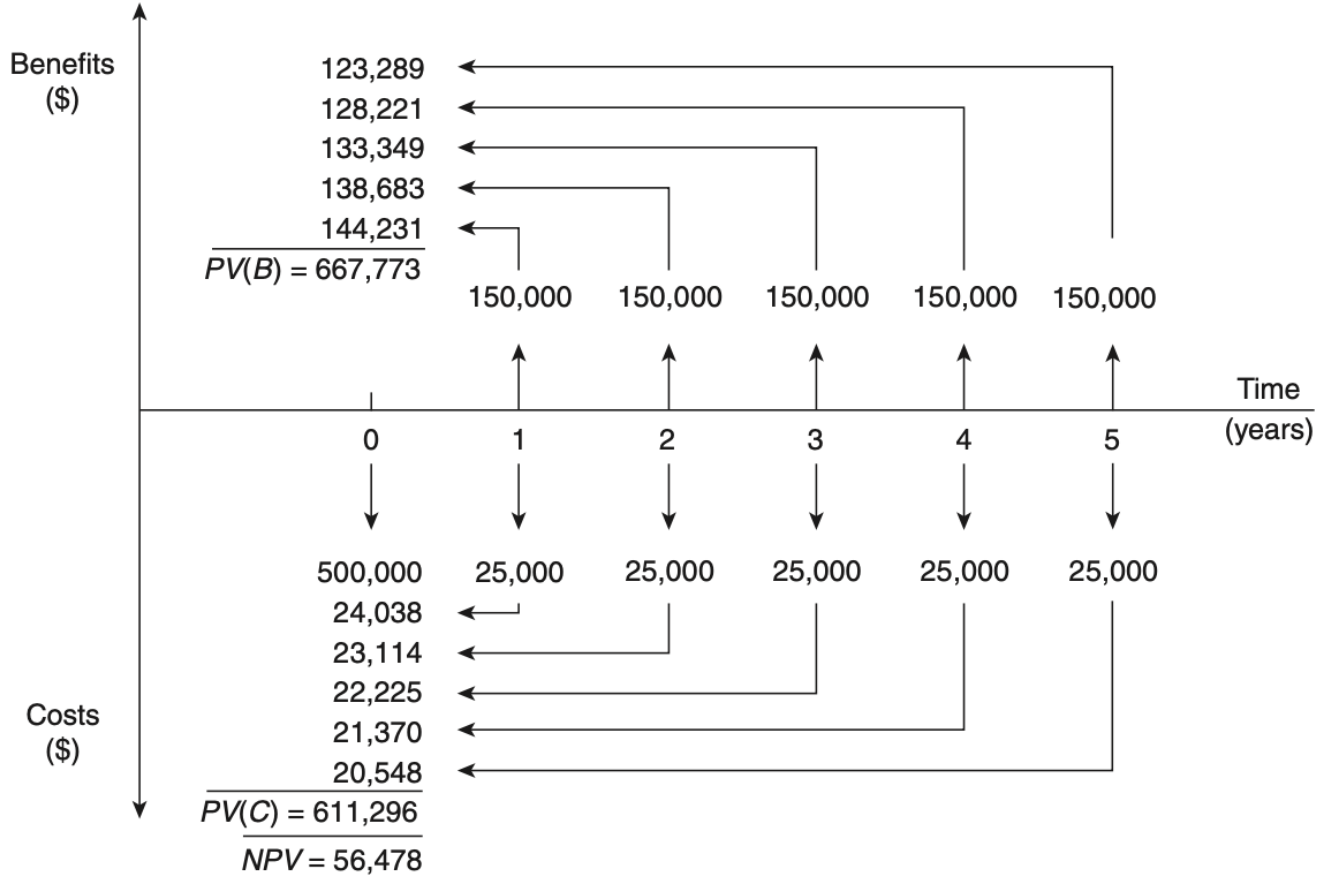
NPV < 0 ➔ Do not Invest

Year	Event	Annual benefits	Annual costs	Annual net social benefits
0	Purchase and install	0	500,000	–500,000
1	Annual benefits and costs	150,000	25,000	125,000
2	Annual benefits and costs	150,000	25,000	125,000
3	Annual benefits and costs	150,000	25,000	125,000
4	Annual benefits and costs	150,000	25,000	125,000
5	Annual benefits and costs	150,000	25,000	125,000
	PV	667,773	611,296	56,478



Investment criteria : Benefit-Cost ratio

$$B/C = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$



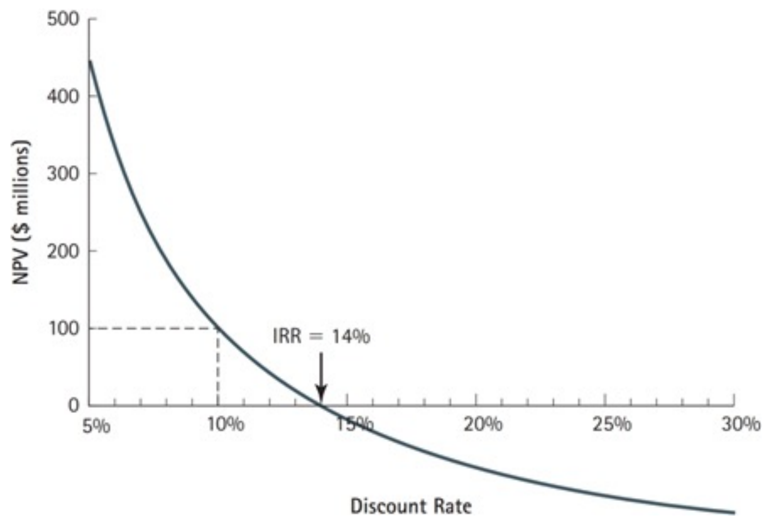
B-C ratio > 1 ➔ Invest

B-C ratio < 1 ➔ Do not Invest

$$\text{B-C ratio} = \frac{667{,}773}{611{,}296} = 1.0923$$

Investment criteria : Internal Rate of Return(IRR)

- IRR = Discount Rate (r) at which NPV =0



$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+IRR)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+IRR)^t} = 0$$

In most cases the IRR is calculated by trial and error. This is accomplished iteratively by guessing different interest rates to use in the IRR formula until one is found that causes the net present value to equal zero.

- IRR > borrowing rate (hurdle rate) ➔ invest
- IRR < borrowing rate (hurdle rate) ➔ do not invest

IRR

$$NPV = -100 + \frac{50-10}{(1+IRR)} + \frac{50-10}{(1+IRR)^2} + \frac{50-10}{(1+IRR)^3} + \frac{50-10}{(1+IRR)^4} + \frac{50-10}{(1+IRR)^5} = 0$$

Try r = 20% $$NPV = -100 + \frac{40}{(1.2)} + \frac{40}{(1.2)^2} + \frac{40}{(1.2)^3} + \frac{40}{(1.2)^4} + \frac{40}{(1.2)^5} = 19.62$$ r is too low

Try r = 30% $$NPV = -100 + \frac{40}{(1.3)} + \frac{40}{(1.3)^2} + \frac{40}{(1.3)^3} + \frac{40}{(1.3)^4} + \frac{40}{(1.3)^5} = -2.58$$ r is too high

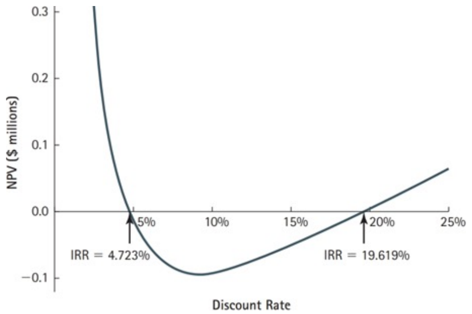
r at which NPV = 0 is 28.65%

IRR Limitations

- Multiple IRRs or no IRRs :They occur when a project has nonconventional cash flows. Nonconventional projects are ones that involve outlays (cash outflows) not only at the beginning but also later. In other words, for nonconventional projects cash flows change signs more than once.

Time	Amount
0	-$10,000
1	$60,000
2	-$110,000
3	$60,000

IRR	0.00%
IRR	100.00%
IRR	200.00%



- Timing of the cash flows can impact the profitability of an investment, but this won't always be indicated by the IRR. As a result, the IRR could conflict with net present value.

Year	Cash Flow	
0	-$100,000	
1	$15,000	
2	$15,000	
3	$15,000	
4	$15,000	
5	$15,000 +	$69,475

IRR	10.00%
Total Cash Flow	$144,475
NPV	$44,475

Year	Cash Flow	
0	-$100,000	
1	$0	
2	$0	
3	$0	
4	$0	
5	$0 +	$161,051

IRR	10.00%
Total Cash Flow	$161,051
NPV	$61,051

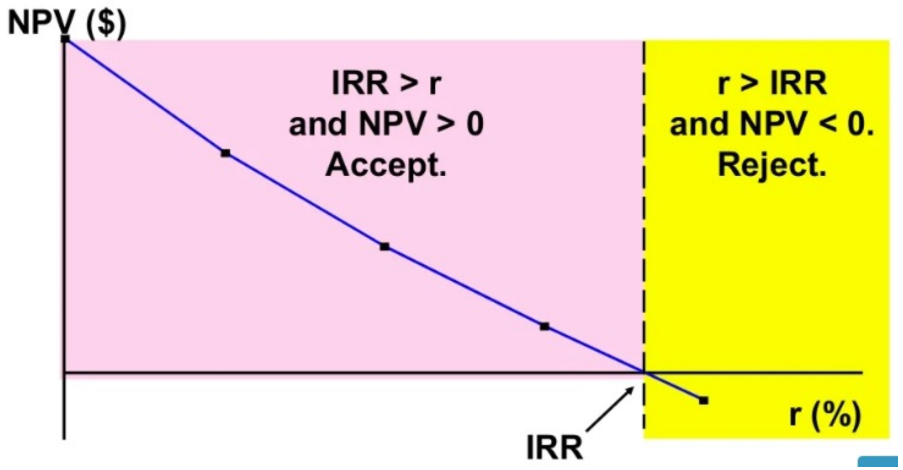
- **IRR ignores the size of the project**. That means the project with the highest IRR won't necessarily be the project with the highest profit. For example
  - Option 1: Invest 100 at time 0 and get back 200 at time 1. This results in a 100% IRR, and a gross profit of 200-100 or 100.
  - Option 2: Invest 1,000,000 at time 0 and get back 1,100,000 at time 1. This results in a 10% IRR, and a gross profit of 1,100,000 – 1,000,000, or 100,000.

Even though option 1 has a higher internal rate of return, option 2 has the highest profit.

Independent and Mutually Exclusive Projects

Independent projects are ones being evaluated that could potentially all be selected as long as their projected CFs will produce a positive NPV or generate an IRR greater than the firm's hurdle rate.

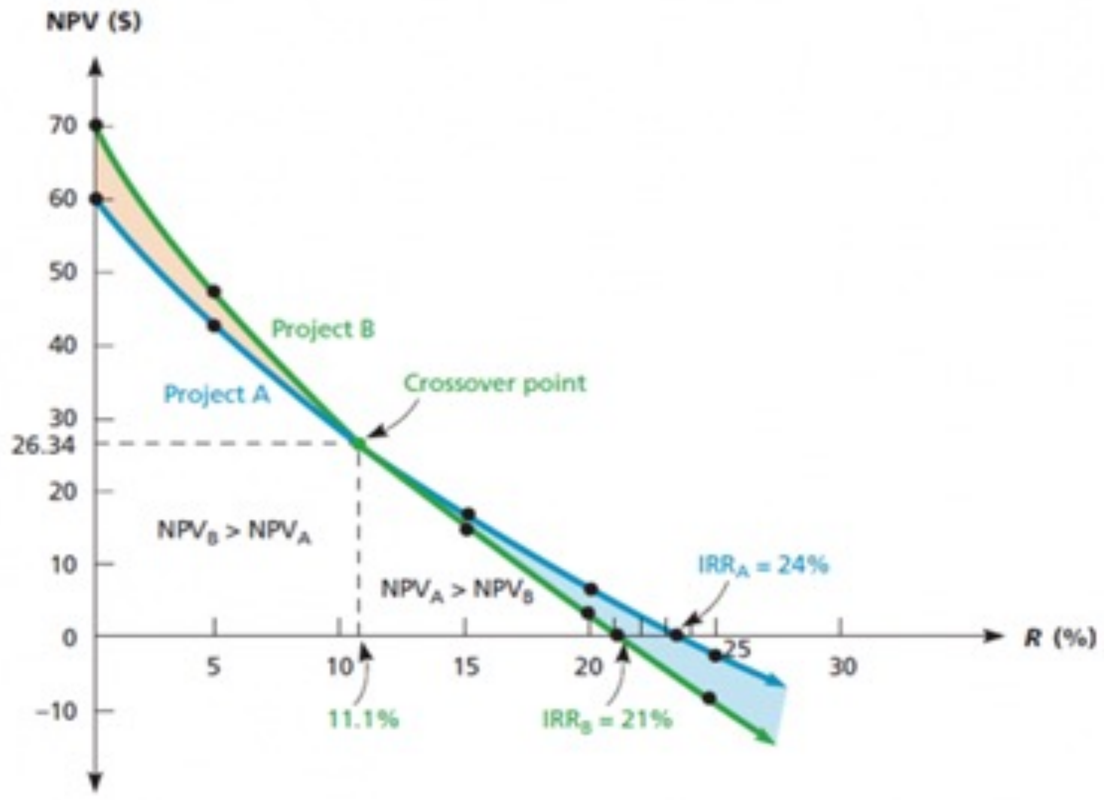
- there will be no conflict over whether to accept a project or not regardless of the criterion you use.



Independent and Mutually Exclusive Projects

In mutually exclusive projects, all projects are to accomplish the same task. Therefore, such projects cannot be undertaken simultaneously. only one project can be accepted.

- An example of mutually exclusive projects would be the option of a manufacturer to (a) expand its existing plant or (b) build a new one on a separate site in order to increase production capacity.
- The project that offers the higher NPV and IRR would be picked.
- When deciding to pick between the projects, the NPV and IRR decision rules (assuming all are profitable) can be in conflict because of time horizon and cash flow differences between the two projects.
- If there is such a conflict, you should always choose the project with a higher positive NPV.



BCA Example

Climate change adaption project : Household rainwater tank project

- Niue, the Republican of the Marshall Island
- Extreme rainfall ➔ higher chance for groundwater contamination ➔ lower water supply quality
- Project: household rainwater tank to reduce risk of water supply quality and improve water supply services

Cost	Benefit
1. Purchase of tank 2. Installation cost 3. Maintenance cost	1. Improve water supply quality = avoided medical cost + avoided lost income 2. Improve water supply reliability = value of time saved from not having to collect water from reservoir tanks 3. Reduced groundwater pumping costs of 4. Reduced imports of bottled water

Change adaption project : Household rainwater tank project

	Economic results	
	5,000 litre HDPE rainwater tank	**10,000 litre HDPE rainwater tank**
(1) Present value of costs at 4% discount rate	$6,058	$7,006
(2) Present value of benefits at 4% discount rate		
Improved water supply quality	*$153*	*$153*
Improved water supply reliability	*$4,763*	*$4,763*
Avoided pumping costs	*$835*	*$895*
Avoided imports of bottled water	*$445*	*$445*
	$6,196	$6,256
(3) NPV = (2) – (1)	$138	**–$750**
(4) BCR = (2) / (1)	1.02	**0.89**

Seawall to prevent coastal erosion (Samoa)

Cost	Type of cost	Measurement technique	Approach selected
Equipment cost and labour cost	Direct monetary cost	The equipment costs are recorded in the project documents.	They are included in the analysis because they are accountable for an high percentage of the cost and they are measurable economic costs.
Maintenance cost	Direct monetary cost	Maintenance costs are generally estimated by the constructor.	The maintenance costs are estimated by using existing projects as a reference. We will assume that the costs are the same of a EU Hondsbossche Seawall in Netherlands
Loss of tourism due to the loss of natural ecosystem	Indirect monetary cost. (functional value)	Measurable with businesses income survey.	Due to the modest touristic activity (there are no accommodations in the area) this cost will be not take into account. A regression to be statistically meaningful needs a bigger sample.
Noise pollution due to the construction of the sea wall	Indirect non monetary cost (intangible cost)	Measurable with contingent evaluation method.	The contingent evaluation method is characterized by high level of uncertainty and the influence of this value on the overall cost Is modest, therefore this cost will be assessed by a qualitative point of view.
Alteration of the sea ecosystem with consequent alteration of fishery activity	Indirect monetary cost. (functional value)	Measurable with fishery survey.	These tools can be very expensive and their cost is not justified for the scale of the project.
Alteration of long-shore drift patterns, affecting neighbouring villages	Direct monetary cost	Expected value of area of land loss reduced	Quantitative analysis considering the average value of land in Samoa and measuring the expected land erosion comparing satellite photographs.

Benefit	Type of cost	Measurement technique	Approach selected
Avoided coastal erosion	Direct monetary benefit	Expected value of area of land loss reduced	Quantitative analysis considering the average value of land in Samoa and measuring the expected land erosion comparing satellite photographs.
Avoided loss of infrastructure	Direct monetary benefit	Expected value of Infrastructure loss avoided. The value is estimated measuring assets with a survey.	Quantitative analysis. The value of the infrastructure is measured counting the assets in the expected coastal erosion area. The value of these assets is estimated using related studies values.
Decreased damages to infrastructures caused by cyclones and extreme sea surges.	Direct monetary benefit	Using historical records of sea surges or using models to measure the impacts	Qualitative analysis due to the lack of records of extreme sea surge,cyclones damages in the area and to resources and time constraints.
Decreased cleaning up costs related to extreme sea surges.	Indirect monetary benefit	Multiplying the number of days spent in cleaning up activities by the minimum wage in Samoa. Gill (2003).	Qualitative analysis due to the lack of records of extreme sea surge in the area and to resources and time constraints.
Reduced loss of income and revenue and cleaning up damages	Indirect monetary benefit	Multiplying the number of working days by the average income and revenue.	Qualitative analysis due to the lack of records of extreme sea surge in the area and to resources and time contraints.
Reduced stress and trauma related to sea surges.	Indirect non monetary benefit	Contingent valuation	The contingent evaluation method is characterized by high level of uncertainty therefore this cost will be assessed by a qualitative point of view.

Seawall to prevent coastal erosion (Samoa)

	Economic results
(1) Present value of costs at 8% discount rate	
Capital construction costs	*$462,530*
Maintenance costs	*$167,872*
Environmental impacts	*Not valued*
	$630,402
(2) Present value of benefits at 8% discount rate	
Avoided loss of land from erosion	*$1,276,006*
Avoided relocation costs related to erosion	*$101,741*
Avoided damages and losses from flooding	*Not valued*
	1,377,748
(3) NPV = (2– (1)	$747,346
(4) BCR = (2) / (1)	2.19

Seawall to prevent coastal erosion (Samoa)

Variables	Primary results		Sensitivity test results	
	NPV ($)	BCR	NPV ($)	BCR
(i) Rate of coastal erosion without intervention (1.33 m/ year)	$747,346	2.19	$2,042,686	4.24
(ii) Effectiveness of seawall in mitigating erosion (erosion rate with seawall is 0.33 m/year)	$747,346	2.19	$109,343	1.17
(iii) Value of land (50% of Apia prices)	$747,346	2.19	$109,343	1.17
(iv) Discount rate (4%)	$747,346	2.19	$1,253,379	2.77

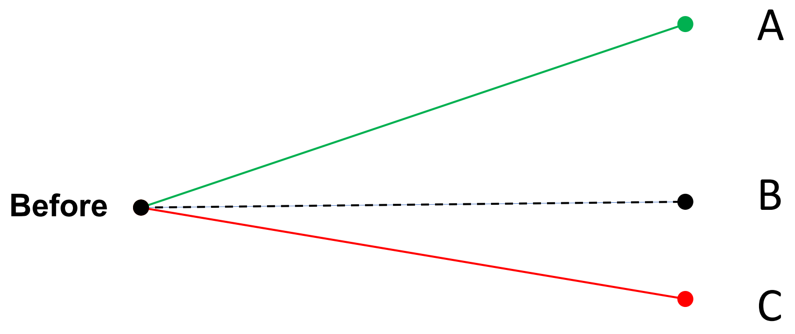
A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the rate of coastal erosion without any intervention. This was modelled as 1.33 metres per year – a rate considered possible if climate change effects are 'worst-case'; (ii) the effectiveness of seawall in mitigating erosion. This was modelled as reducing erosion rate to 0.33 metres per year rather than 0 metres per year, which is considered possible if the seawall is not properly maintained; (iii) the value of land. This was modelled at 50% lower than values used for Apia. Tafitoala is some 46 km from Apia; and (iv) the discount rate. A 4% discount rate was modelled in addition to the 8% rate used by Samoa Government so as to be consistent with other PACC CBAs. 4% is the worldwide average real market interest observed for the last 150 years.

Links to interesting articles about discount rate

1. https://zielonygrzyb.wordpress.com/2011/06/19/discounting-in-the-economics-of-climate-change/
2. http://grist.org/article/discount-rates-a-boring-thing-you-should-know-about-with-otters/
3. https://www.sciencenews.org/article/discounting-future-cost-climate-change

Cost and Benefit of a project

- With-and-Without Project VS Before-and-After Project.
- Example, irrigation projects for climate change adaptation.
- The benefit of the irrigation system is changes in agricultural productivity.



Cost and Benefit of a project

Categories of Change	Current Climate Variability and Change	Climate Change in the Future
Current Social and Economic Context	This cell represents the current situation: today's social and economic contexts and the ways in which weather events affect them. Governments and citizens address these challenges routinely. Those in the field of disaster risk reduction (DRR) address the impacts of extreme weather events and have done so since before climate change became a concern. If capacity (investments, resources, skills, etc.) is insufficient to address today's weather disasters, this gap is referred to as the development deficit or the adaptation deficit.	Future needs will differ from current ones in part because of expected changes in climate.
Future Social and Economic Context	Even without climate change, population growth and economic change would lead to changes in development needs.	Projections of future needs will have to factor in both climate change and social and economic growth.

Cost and Benefit of a project

	Coastal Flooding	Agriculture	Health	Ecosystems and Biodiversity
Step 1: Current Situation	Use a geographic information system (GIS) to determine which land is now at risk of flooding, and who or what is there now.	Determine what is happening now with respect to the issue of interest; e.g., what is growing in a given place and how; or what the sources, prices, and technologies are for the current food supply.	Identify current spatial distribution of the disease of interest or of the species that transmit that disease to humans.	Locate key ecosystems in a GIS. Determine which communities now depend on those ecosystems, and how.
Step 2: Climate Change	Use the GIS to see which land will be flooded in the future, based on projections of sea-level rise and storm surges, combined if possible with data on local coastal features.	Predict how anticipated long-term changes in weather will affect the baselines suggested in the first step.	Determine how change in climate conditions will affect the survival of the disease itself or of the species that transmits it. If medicine does not yet know how the disease or the vector for transmission is affected by climate, further medical research will be needed.	Use downscaled climate data to predict which ecosystems will be at risk of floods, drought, and so on.
Step 3: Social and Economic Change	Obtain projections of population growth, migration, urbanization patterns, deforestation patterns, etc. to determine who or what will be affected by future floods.	Specific projections will depend on what issue is of interest; they may focus on changes in population, access to farmland, trends in non-food uses of farmland (e.g., biofuels), demand for food, prices, and other trends that may influence food supply from either the supply or the demand side.	Obtain predictions of population in the areas that will be exposed to the disease under future weather conditions.	Project growth of population dependent on the ecosystem.
Step 4: Project Exposure to Climate Change in Future	Overlay the future floods with the future land use to assess the impacts.	Various models can predict the outcome, depending on the issues of interest. Agronomic models look specifically at how climate changes affect crop yields. Macroeconomic models will develop new balances in food markets based on trends in agricultural output, population, and so on.	Overlay spatial data on areas where the disease will be present with projected population data in order to determine exposure levels. Combine this with statistical data on the probability of catching the disease and with Disability Adjusted Life Years (DALYs) from the disease to estimate total impact.	Overlay population projections with projections of climate threats to determine how communities dependent on the ecosystems will be harmed.