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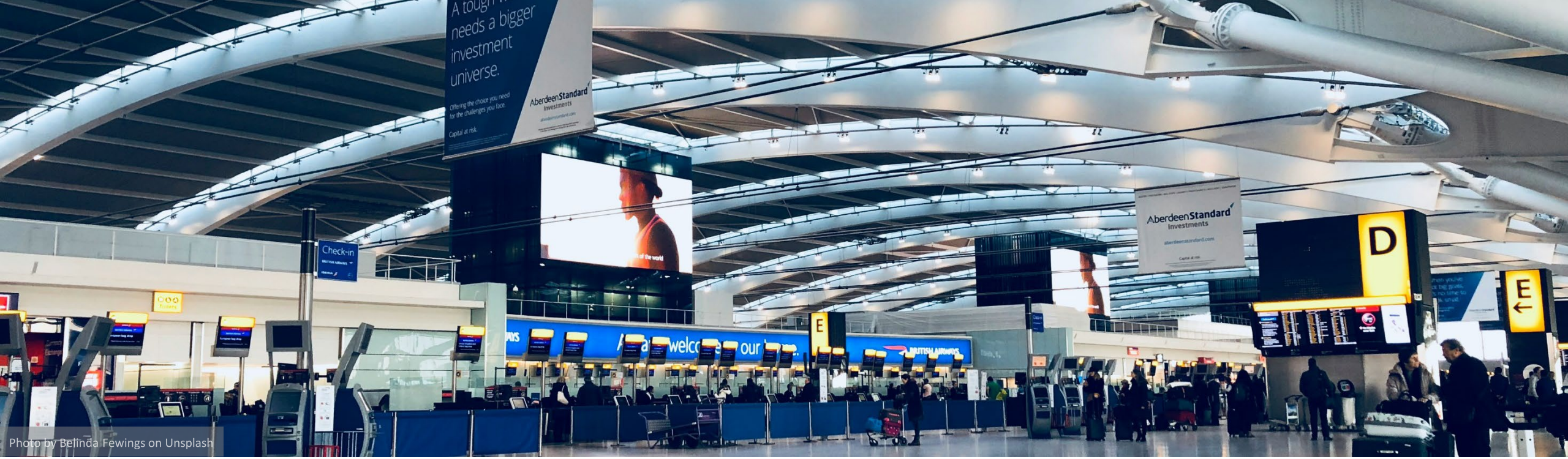

Photo by Belinda Fewings on Unsplash

Workshop on Strategic Planning Focused on Air Navigation and Airports, Including Guidance for Decision-making Based on Cost-Benefit Analysis (CBA)

Mexico City, Mexico, 17 to 20 September 2024

Daniel Tha daniel.tha@kralingen.com.br

Antônio Marcos Oliveira amarcosfo@gmail.com

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Workshop overview

01 The case for economic project and regulatory appraisal

02 Planning Fundamentals and Project design

03 Identifying Relevant Costs and Benefits

04 Estimating costs, benefits and externalities

05 Calculating economic viability indicators

06 Dealing proactively with risk and uncertainty

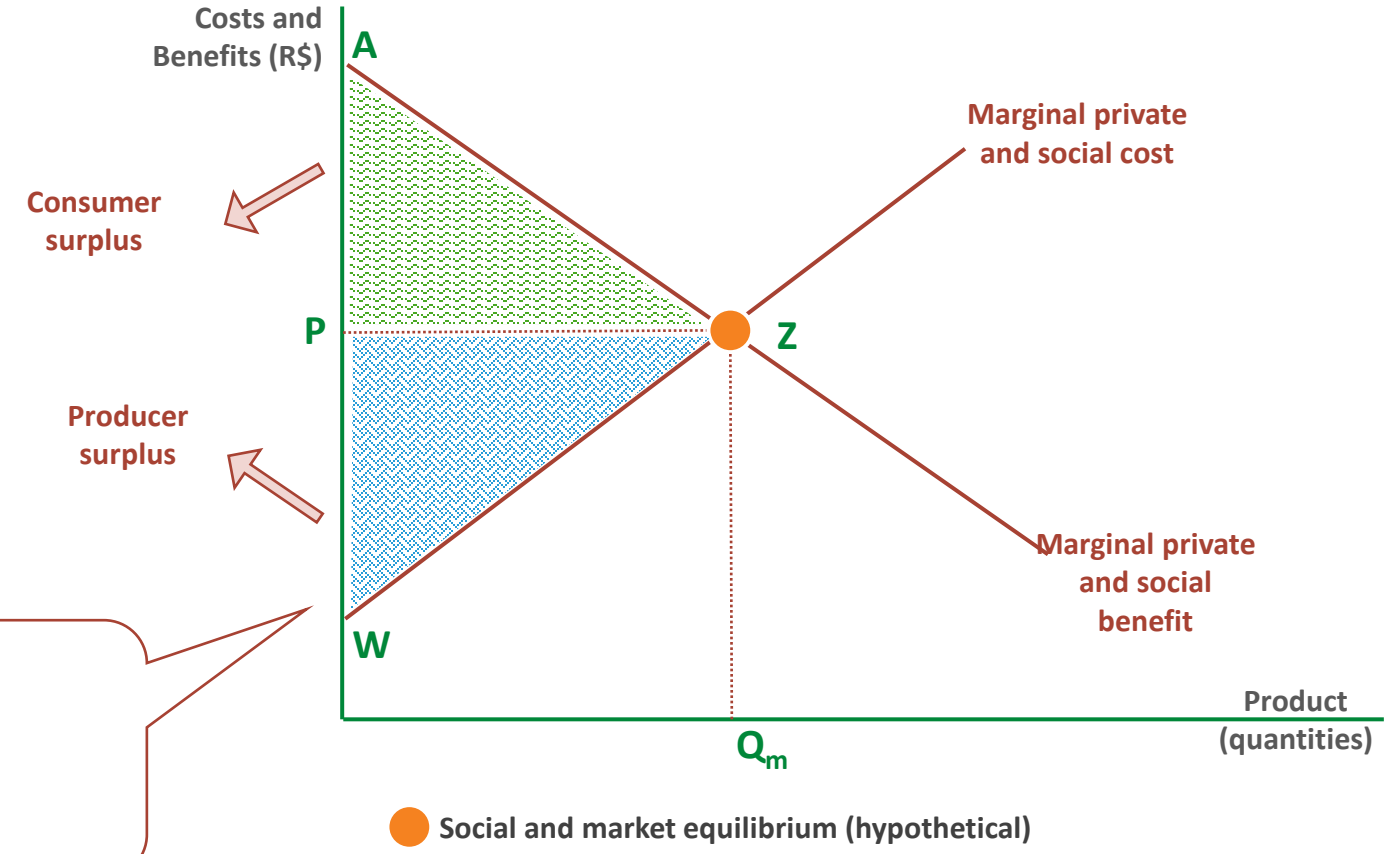
01a

Why an “economic” appraisal?

Photo by Simon Mumenthaler on Unsplash

Socio-economic = Social welfare = Social surplus

In **hypothetically perfect markets**, market prices equal social prices and the **allocation of scarce production resources is efficient**



Consumer surplus (PAZ)
+
Producer surplus (WPZ)
=
Social surplus (WAZ)

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Various sources of market distortion

Fiscal components e.g. direct and indirect taxes, tariffs, duties

Subsidies e.g. administered tariffs, transfers, rebates or exemptions

Market structure e.g. monopolies, oligopolies, oligopsonies

Information asymmetry e.g. beef from deforestation

Free/open access e.g. lack of property rights

Externalities (positive and negative), common and public goods e.g. air pollution, ecosystem services, deforestation, security

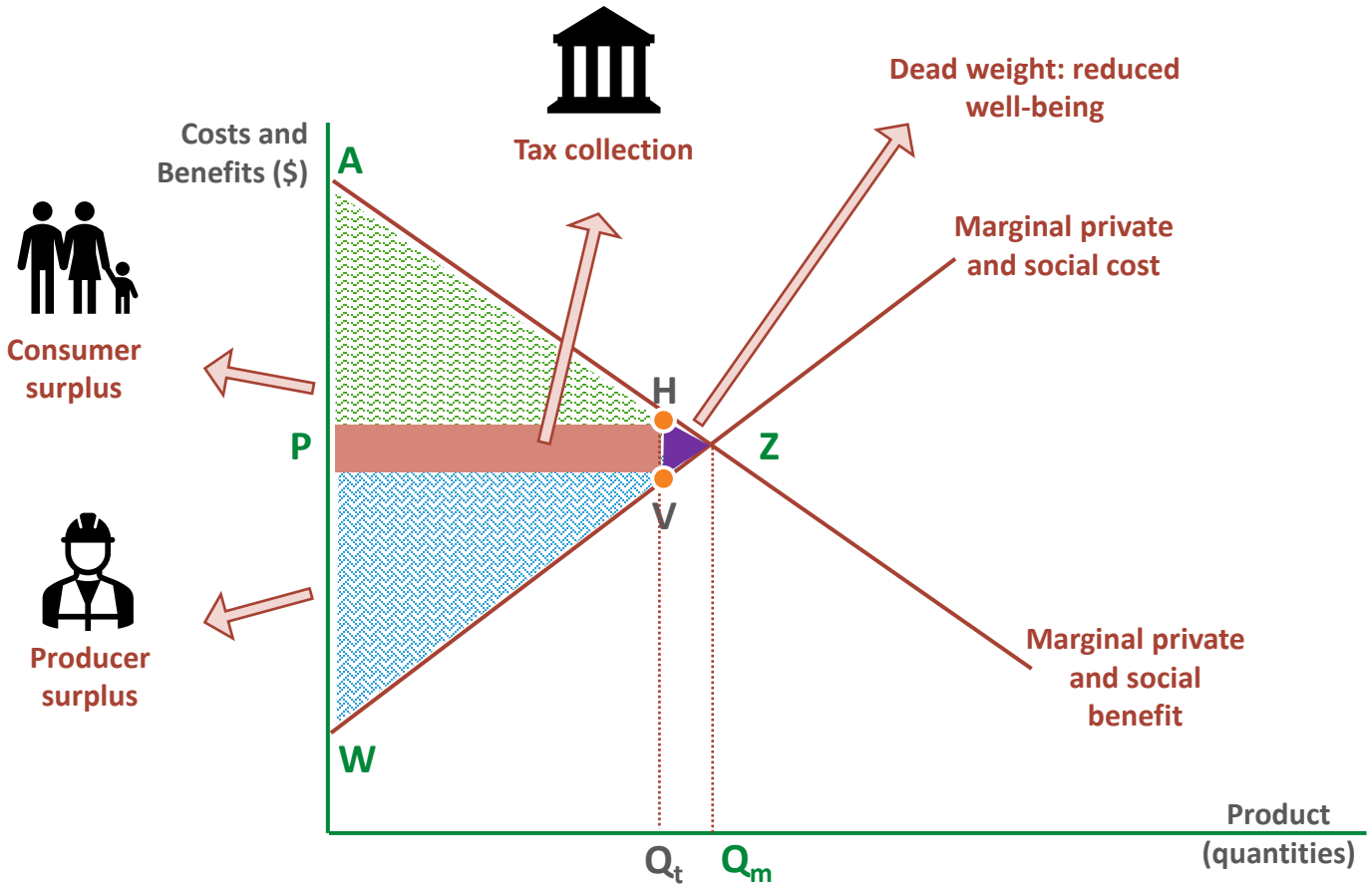
Distortions generate losses of allocative efficiency...

In the presence of distortions:

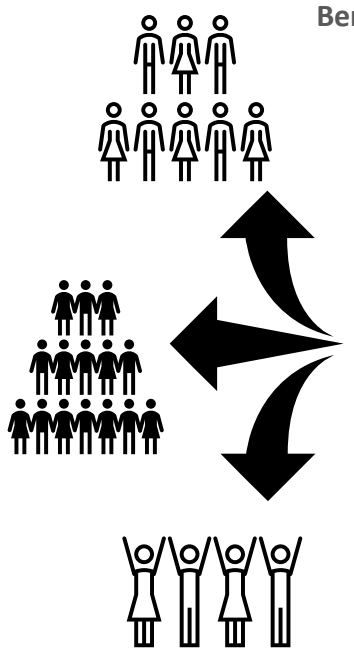
market prices

≠

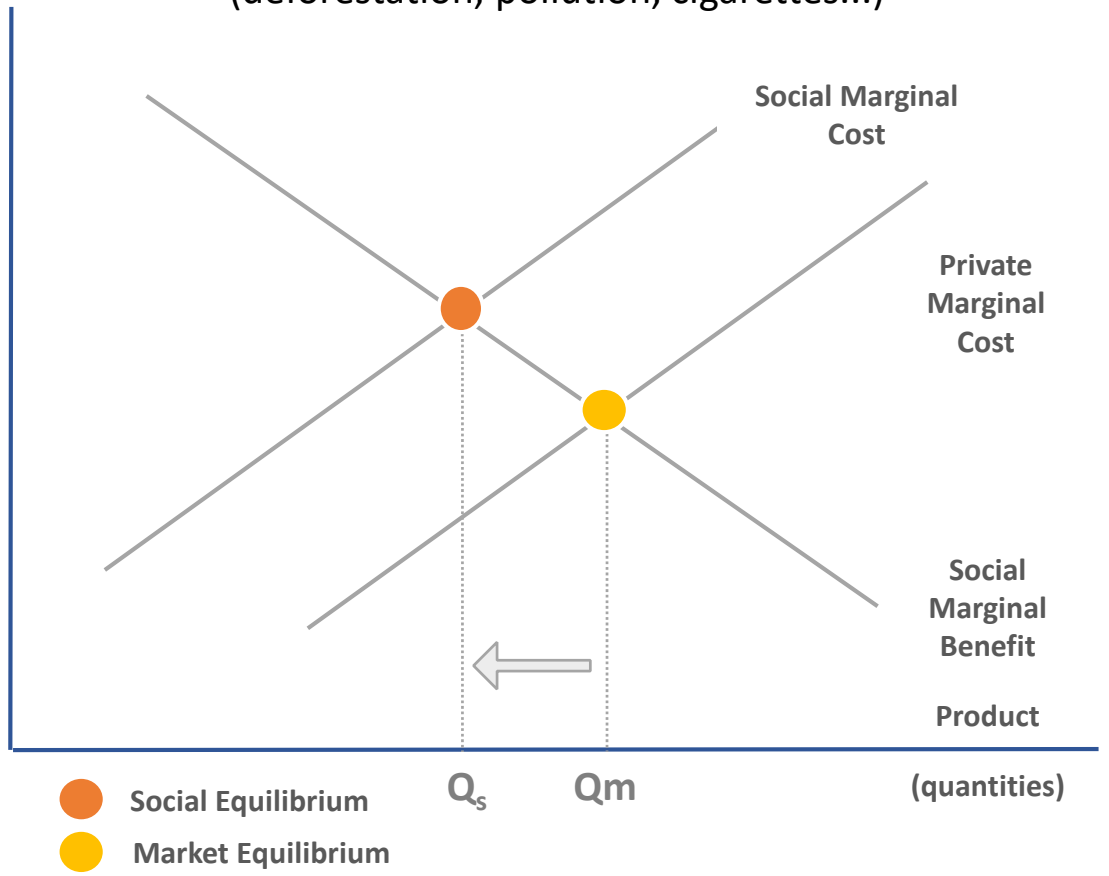
social prices



Market failures and externalities allocate resources sub-optimally



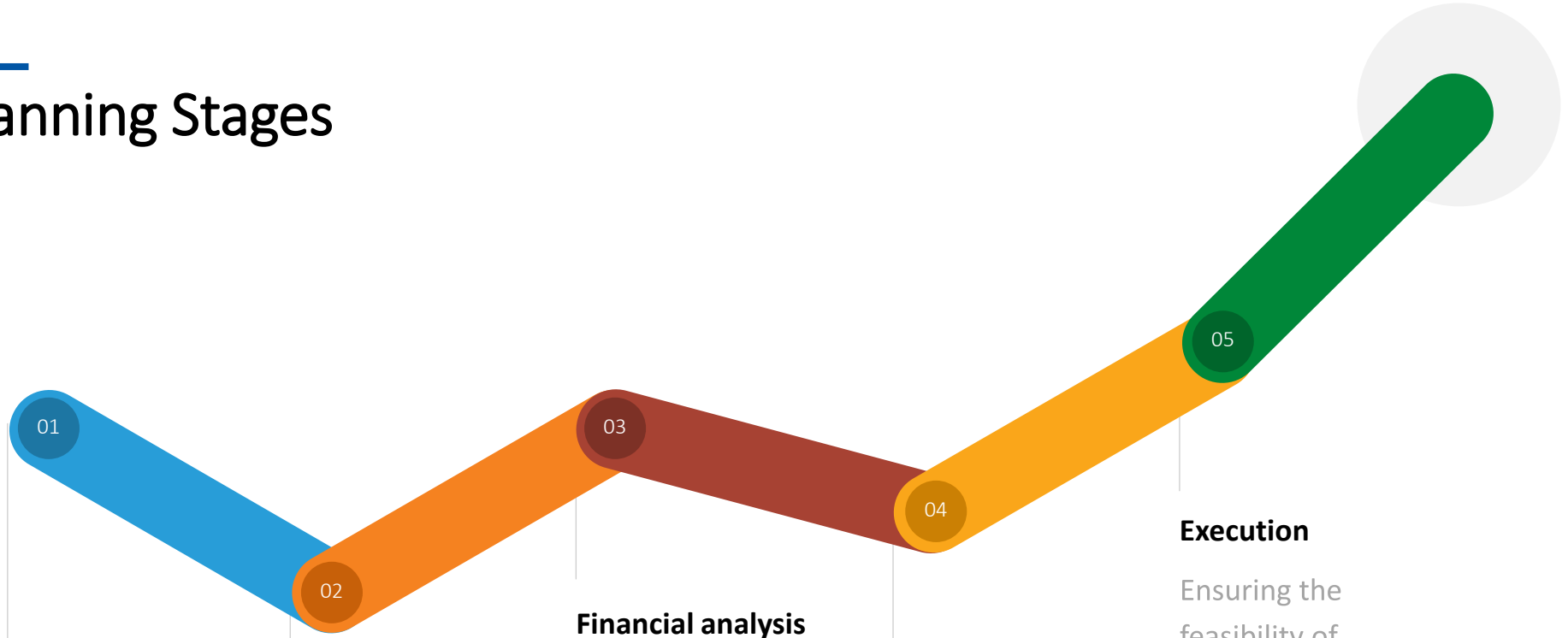
Example of a negative externality
(deforestation, pollution, cigarettes...)



Airports and air control are of “economic” interest

- **Competitiveness**: facilitates trade and investment
- Impact on the economy's **productivity and efficiency** (travel costs and time, supplies)
- Implications for **regional development**
- Improving routes and procedures has direct implications for society and the environment
- Air traffic flow management provides **safety and predictability**
- Reducing greenhouse gas emissions
- Interactions with land use, densification, urban flows, and mobility

Planning Stages



Strategic dimension

Ensure that projects are in line with the strategy

Economic analysis

Ensure that the chosen alternative delivers the best cost-benefit ratio for society

Financial analysis

Determine the appropriate contracting model

Contracting

Verify resources for project execution

Execution

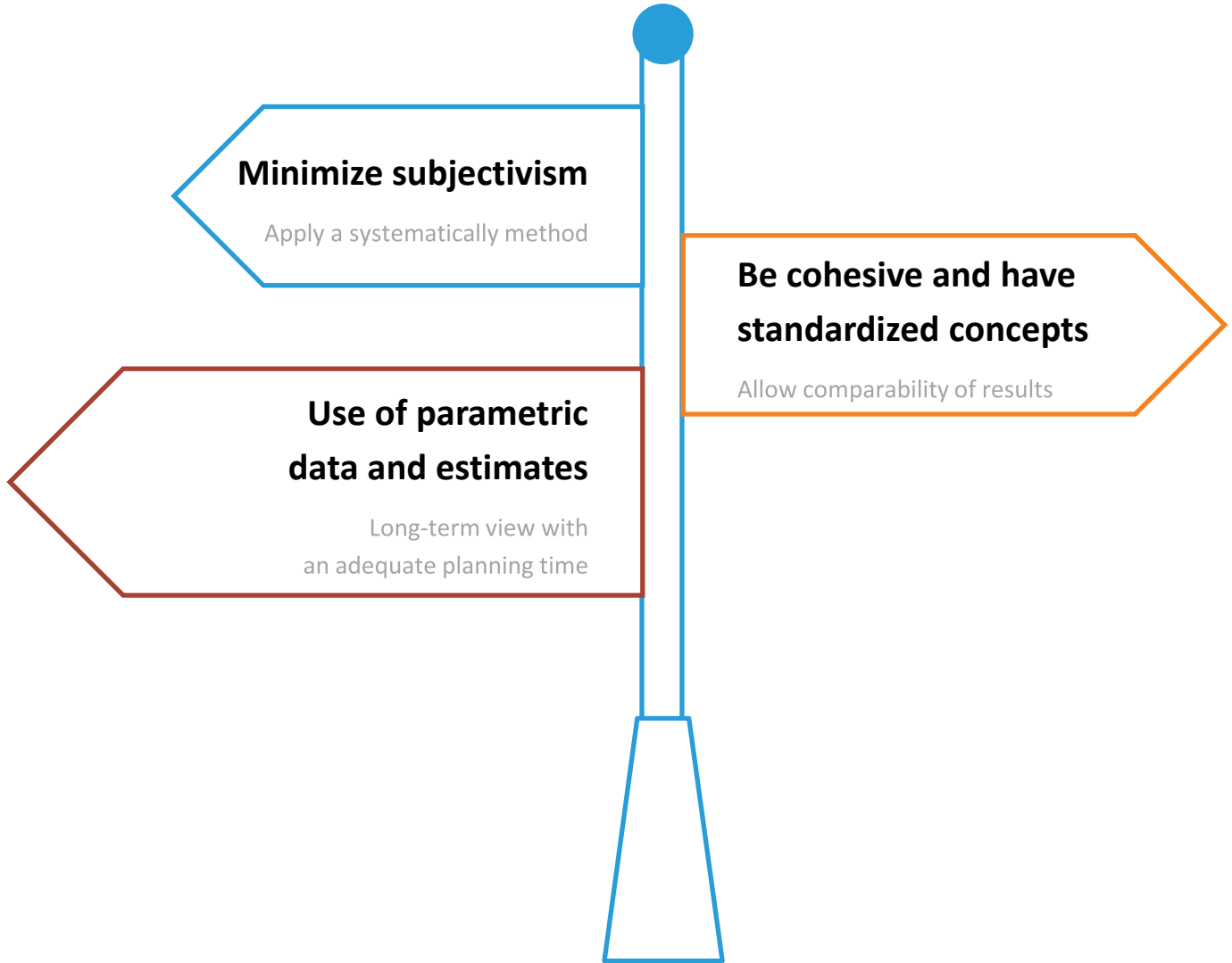
Ensuring the feasibility of deliveries

Economic Appraisal's Importance

Good planning = Good delivery!

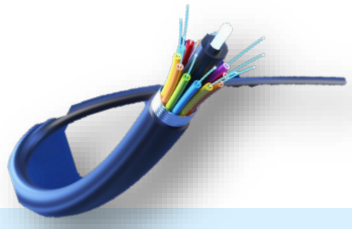
- Ensure that the project stems directly from social problems that need to be addressed
- Ensure that the project delivers the best cost-benefit ratio for society
- Direct execution, Public concession, PPP, Partnership, Subsidized financing, Tariff collection, Cross-subsidization...
- Guaranteed funding and "social license" to operate

How can we get there?



Different focus of analysis

Financial Valuation (Private)	Socio-economic assessment
Assumes the perspective of the entrepreneur / company / firm / project manager	***Assumes the perspective of society (family, companies, and government) in a given territory***
Considers cash (income and expenses) to and from the agent (e.g. entrepreneur) at market prices	*Considers all costs, benefits and externalities at social prices, which impact society as a whole*
Discounted cash flow at the weighted average cost of capital (WACC), reflecting the firm's opportunity cost	*Discounted flow of C & B at the social discount rate (TSD), reflecting society's opportunity cost*
- Net Present Value (NPV)	***- Comparative Net Present Social Value (ΔNPSV)***
- Internal Rate of Return (IRR)	***- Economic Rate of Return (ERR)***



Providing broadband services

Financial Valuation (Private)	Socio-economic assessment
Revenue categories (+)	***Benefit categories (+)***
• Revenue from data transmission services	• Benefits of increased worker productivity in companies
• Revenue from assignment of fiber and infrastructure use	• Household consumer surplus/WTP
Expenditure categories (-)	***Cost categories (-)***
• Investment cost at market prices	• Social cost of investment
• Operating costs at market prices	• Social cost of the operation

Financial value

Correction of market distortions (monopolies, subsidies, information asymmetry and externalities) and assessment of non-market impacts and externalities

Well-being value

Construction of a new passenger terminal at an airport

Financial Valuation (Private)	Socio-economic assessment
Revenue categories (+)	***Benefit categories (+)***
• Tariff revenue (passengers and companies)	• Passenger time savings
• Non-tariff income (commercial leasing, parking...)	• Passenger comfort
Expenditure categories (-)	***Cost categories (-)***
• Investment cost at market prices	• Social cost of investment
• Operating costs at market prices	• Social cost of the operation

Financial value

Correction of market distortions (monopolies, subsidies, information asymmetry and externalities) and assessment of non-market impacts and externalities

Well-being value

		Socio-economic assessment	
		Feasible	**Unviable**
Financial Valuation (Private)	**Profitable**	**A**	**D**
	Unprofitable	**C**	**B**

- **Situation A** = No conflict, situation with easy decision and financing
- **Situation B** = Bad project, generally not carried out (no interest)
- **Situation C** = Social project (financing ***gap***); Government finances or forms PPP
- **Situation D** = **Negative** externality for society (society loses, even if an actor gains); Government must use regulatory function to curb it!

01b

Upstream planning advantages

Photo by Praveen Thirumurugan on Unsplash

Projects that do contribute to society's wellfare but would not have been carried out

European Union Cohesion Fund (bridging the financial gap)

Average results of projects approved between 2011 and 2016

Different views:		
SECTOR	**Financial rate of return (%)**	**Economic rate of return (%)**
Transportation	-3.9	14.4
Environmental infrastructure	-3.7	14.7
Research, development, and innovation	0.7	21.1
Energy infrastructure	3.5	16.0
Information and communication technologies (ICT)	-6.4	33.8
Health infrastructure	-1.6	18.5
Overall average (various sectors)	-2.9	16.2

Florio, M., Morretta, V., Willak, W. 2018. Cost-Benefit Analysis and European Union Cohesion Policy: Economic Versus Financial Returns in Investment Project Appraisal. J. Benefit Cost Anal. 2018; 9(1):147-180.

Upstream planning advantages: Reduced conflict

IDB mapped 200 local conflicts related to infrastructure projects in Latin America (53 in transportation, 5 of them airports), finding **delays in 81% of the cases** and **cost overruns in 58%** of them, as well as project redesign (42%) and cancellation (18%)!

On average, projects in this sample were **delayed by five years**, incurring additional costs of around US$1.2 billion, or **69% of their original budgets**

FIGURE 8. SUMMARY OF GOVERNANCE DRIVERS OF CONFLICT, ALL PROJECTS.

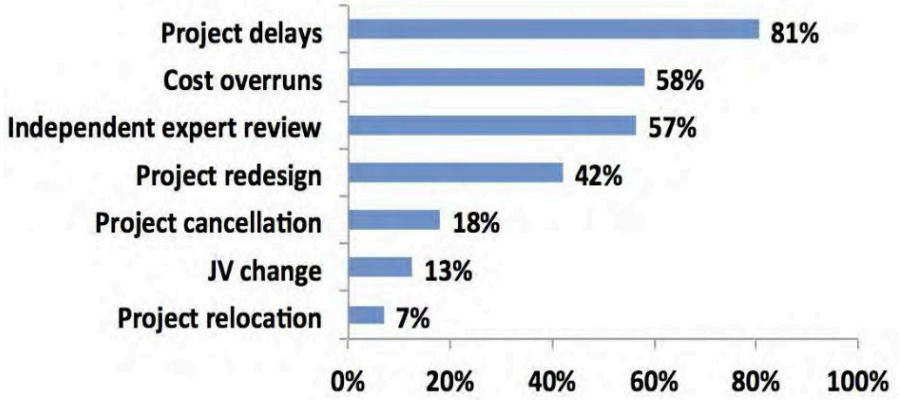


FIGURE 11. SUMMARY OF CONSEQUENCES OF CONFLICT AT THE PROJECT LEVEL, ALL PROJECTS.

BID/IDB [Inter-American Development Bank]. 2017. Lessons from four decades of infrastructure project related conflicts in Latin America and the Caribbean. [Watkins, G.; Mueller, S-U.] Inter-American Development Bank. https://publications.iadb.org/publications/english/document/Lessons-from-Four-Decades-of-Infrastructure-Project-Related-Conflicts-in-Latin-America-and-the-Caribbean.pdf

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Upstream planning advantages: Optimism bias can be managed

Only 8.5% of the projects in the Oxford database met the cost and schedule targets, while only 0.5% also met the benefit targets

Projects with modular construction performed better

Flyvbjerg, B., & Bester, D. 2021. The Cost-Benefit Fallacy: Why Cost-Benefit Analysis Is Broken and How to Fix It. Journal of Benefit-Cost Analysis, 12(3), 395-419. [https://www.cambridge.org/core/journals/journal-of-benefit-cost-analysis/article/abs/costbenefit-fallacy-why-costbenefit-analysis-is-broken-and-how-to-fix-it/608C8A0D37D38653846B9CF9DBC1DB49]

Project type	Mean cost overrun (%)	Projects (A) with ≥50% overruns (%)	Mean overruns of A projects (%)
Nuclear storage	238	48	427
Olympic Games	157	76	200
Nuclear power	120	55	204
Hydroelectric dams	75	37	186
IT	73	18	447
Nonhydroelectric dams	71	33	202
Buildings	62	39	206
Aerospace	60	42	119
Defence	53	21	253
Bus rapid transit	40	43	69
Rail	39	28	116
Airports	39	43	88
Tunnels	37	28	103
Oil and gas	34	19	121
Ports	32	17	183
Hospitals, health	29	13	167
Mining	27	17	129
Bridges	26	21	107
Water	20	13	124
Fossil thermal power	16	14	109
Roads	16	11	102
Pipelines	14	9	110
Wind power	13	7	97
Energy transmission	8	4	166
Solar power	1	2	50

Upstream planning advantages:
Promoting climate resilience

Co-Benefits

Energy efficiency ⇔ Cleaner air

Resilience *through the project*

Raising roads and increasing drainage capacity in Miami-FL

Resilience of the project

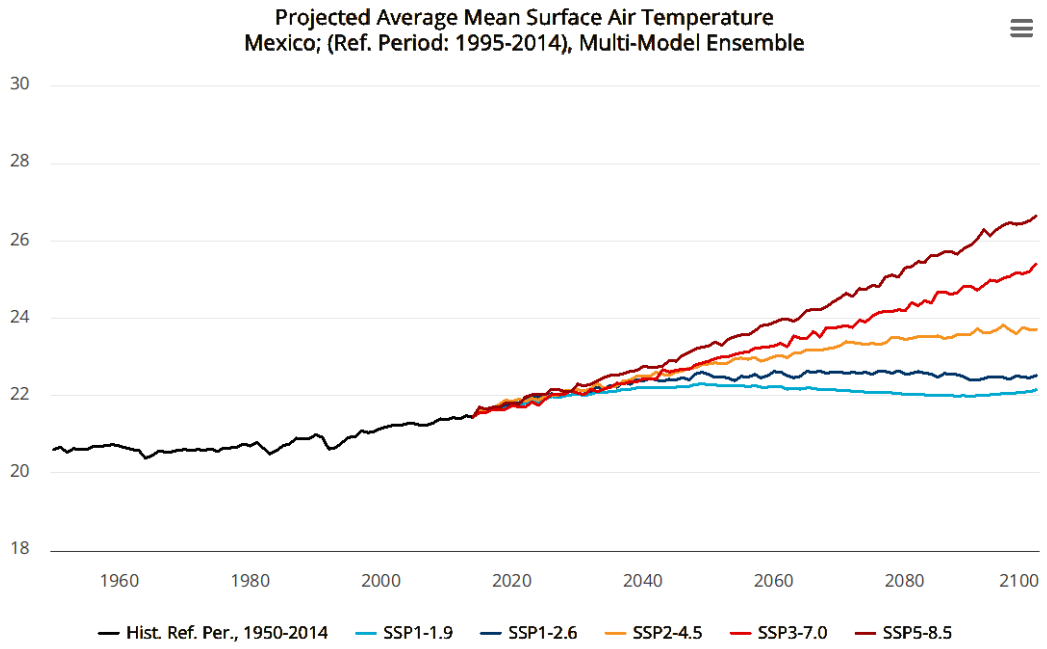
Installation of generators for backup power

Climate threat profile (didactic)

CHRONIC threats

Changes in **climatology (climate)**

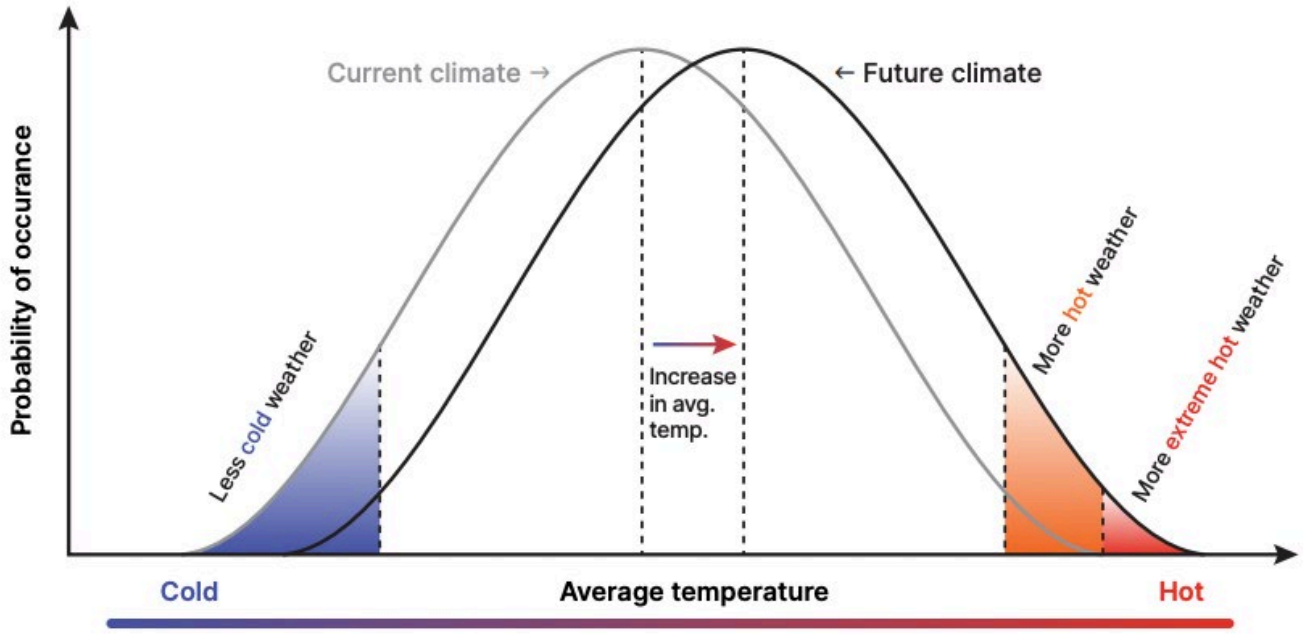
- Average temperature increase
- Progressive change in rainfall patterns
- Rising sea levels...



ACUTE threats

Changes in the **frequency** and/or **intensity** and/or **spatial extent** of **climatic extremes (weather)**

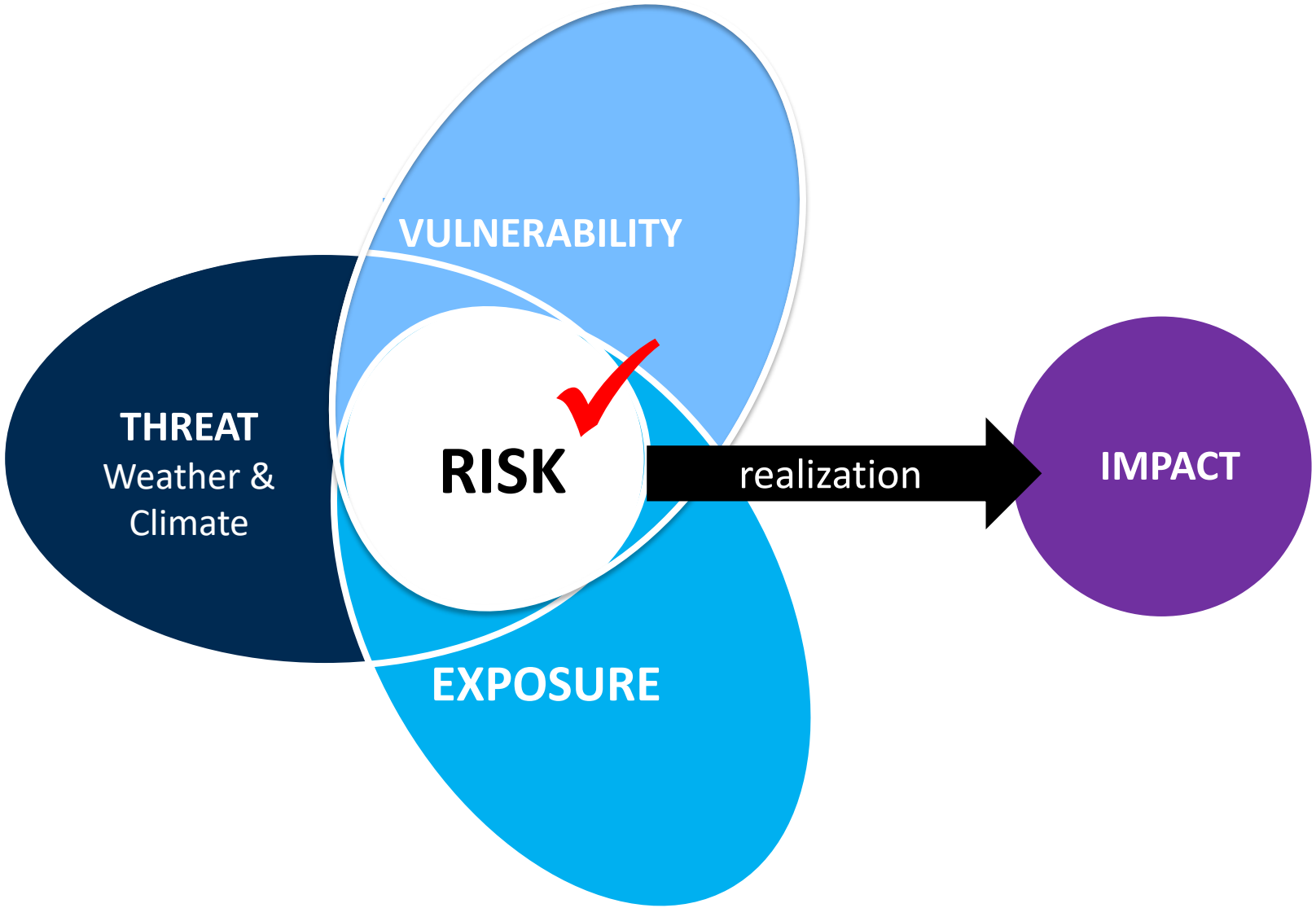
- Storms, floods
- Heat or cold waves, droughts...



https://climateknowledgeportal.worldbank.org/country/brazil/climate-data-projections

Climate change effects and impacts on air transport

- **Adverse weather conditions**, such as sea fog, heavy rain and changes in wind direction, can lead to the cancellation or delay of air operations
- **Hurricanes, storms, and heavy rains** can damage airport structures, flood runways and terminals, and also affect the surroundings of airfields
- **Extreme temperatures** can cause wear and tear on runway surfaces and can limit the maximum take-off weight of aircraft
- **Changes in climatic conditions** can affect the demand and supply of aerodromes (places that are no longer attractive for a particular economic activity, such as snow or beach tourism).


VULNERABILITY
THREAT
Weather &
Climate
RISK
realization
IMPACT
EXPOSURE

How to deal with the climate threat?

- Climate risk affects demand and supply projections for services, altering the **project design**, **size** (costs) and/or **benefits** and (generally) **externalities**
- Consider the **additional risk** (Δ effect of climate change)
  - *Default* analysis must already incorporate the damage expected from the occurrence of extreme events under current conditions (Base period)
  - To simplify, we can assume that only the probabilities of occurrence (return times) will be affected (the severity is f (unknown combination of its duration and intensity))
- It is necessary to establish the **damage exceedance probability curve**
  - Relationship between the **magnitude of impacts** (in monetary value) and **probability of occurrence** (three or four events and their respective return times)
  - This ratio is used to calculate the **annualized value of the damage**, i.e. what is expected to materialize in any given year during the project's analysis horizon

Largest 1-Day Precipitation for Mexico

Return Levels, Historical: 1985-2014 (center 2000) (mm)

Event	5-yr			10-yr			20-yr			25-yr			50-yr			100-yr		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
Historical	37.41	54.78	83.81	43.74	64.43	100.75	50.47	74.66	120.03	52.64	78.13	126.77	59.33	89.23	149.98	65.62	100.34	177.58

Return Period, Historical: 1985-2014 (center 2000) (years)

Event	25mm			50mm			100mm			150mm			200mm		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
Historical	0.31	0.60	1.41	1.46	5.79	51.77	18.55	744.39	6027.83	110.77	3448.68	12011.79	367.71	5195.36	12542.77

Annual Exceedance Probability, Historical: 1985-2014 (center 2000) (occurrence/year)

Event	25mm			50mm			100mm			150mm			200mm		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
Historical	0.87	2.02	3.57	0.07	0.33	1.01	0.00	0.02	0.15	0.00	0.01	0.05	0.00	0.00	0.02

Future Return Period, 2010-2039 (center 2025) (years)

Event	5-yr			10-yr			20-yr			25-yr			50-yr			100-yr		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
SSP1-1.9	2.67	4.28	6.15	4.60	8.28	13.00	7.83	15.99	28.11	9.27	19.75	36.21	15.57	38.17	80.23	25.95	74.06	181.84
SSP1-2.6	2.90	4.22	6.24	5.10	8.12	13.38	8.89	15.66	29.09	10.61	19.32	37.45	18.34	37.12	83.28	31.38	71.31	189.03
SSP2-4.5	3.01	4.35	6.49	5.31	8.40	13.94	9.28	16.15	30.42	11.09	19.94	39.19	19.09	38.44	87.18	32.76	73.96	198.89
SSP3-7.0	3.07	4.38	6.37	5.44	8.51	13.63	9.53	16.51	29.52	11.41	20.44	37.99	19.83	39.64	84.08	34.24	76.63	188.02
SSP5-8.5	2.99	4.27	6.22	5.26	8.22	13.23	9.13	15.80	28.67	10.88	19.50	36.90	18.70	37.45	81.57	31.86	71.96	181.92

Future Return Period, 2035-2064 (center 2050) (years)

Event	5-yr			10-yr			20-yr			25-yr			50-yr			100-yr		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th

02a

Economic appraisal with CBA

Photo by Ryan Miller on Unsplash

Socio-economic evaluation: society's view

- Computable General Equilibrium - CGE
  - Macroeconomic effects, with possible modules (water, energy...)
- Cost Benefit Analysis - CBA
  - Microeconomic effects, preliminary or complete, comparative
- Cost Effectiveness Analysis - ACE
  - Simpler than the CBA, useful for comparing and ranking projects of the same nature
- Multicriteria Analysis - MCD
  - Very useful for rationalizing difficult choices, one of the criteria can be the (simplified) result of a CBA!
- Others...

CBA: a method with very advantageous characteristics

- Cost Benefit Analysis - CBA
  - Microeconomic effects, preliminary or complete, comparative

Comparative (opportunity cost)
- The benefit/cost ratio is not exclusive to the project, but to the difference between the project and doing nothing (or doing the minimum)

Decision-making tool
- Help with comparisons
- Explains the advantages and disadvantages of a decision
- Minimizes subjectivism

Systematic method
- Adds planning quality
- Climate resilience by design
- Qualifies public funding
- Helps communicate results

Maximizes efficiency
Uses monetary value as a common metric (quantitative method)
+ benefits (including intangibles)
- costs (including externalities

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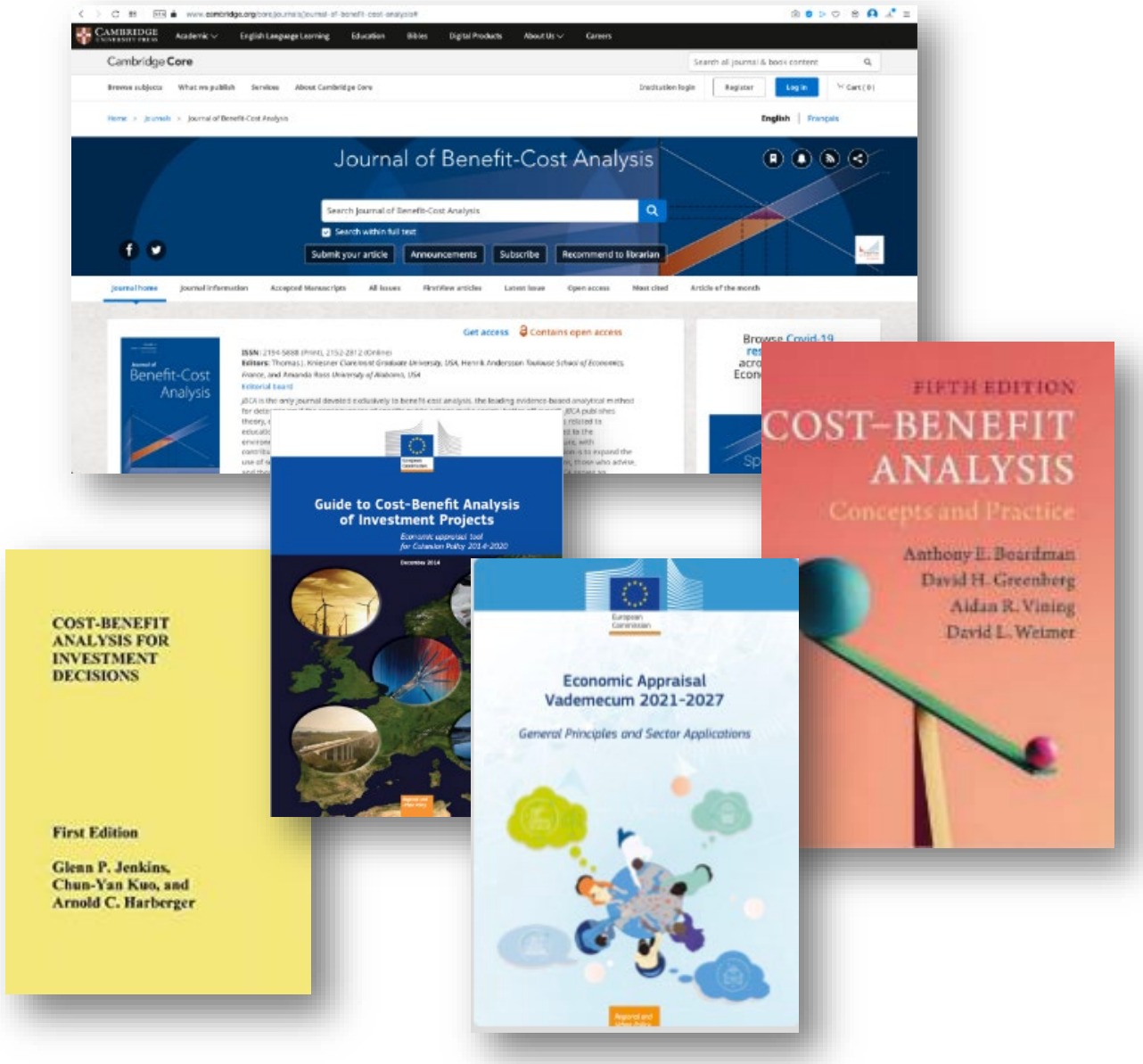
CBA is a well-established method of socio-economic evaluation

... **mandatory in the US** for regulatory acts with a high economic impact since 1980...

... for **analysis of multilateral development** and economic cooperation **projects** by the IDB, IBRD, JICA, ADB, the European Commission...

... 'official' assessment of infrastructure investment, making up a 'decision system': **Chile**, the **United Kingdom**, **Australia**, **New Zealand**, **South Korea**, the **Netherlands**...



CBA can also be used to regulate airports

6.3. ACI recommendations for guidance on airport charges and regulation

Having the above economic characteristics of airports in mind, ACI puts forward the following key recommendations for guidance on airport charges.

Any consideration of whether to regulate, or continue to regulate, airport charges should be subject to a cost-benefit analysis

Regulation should only be used if the benefits of regulation exceed the costs. Governments should require any new regulation of airport charges to be justified by cost-benefit analysis, and they should periodically review whether continued regulation of charges remains justified on a cost-benefit basis.

Group Exercise

Stylized case of economic appraisal

Groups of 4-6

Let's mix skills and perspectives!

The task is to develop a ***conceptual*** case study for air navigation projects

Groups will develop it over the course, so stick to the task at hand right now ->

1st task

What problem are we addressing?

Discuss problems in air navigation and airports that need to be addressed

Choose a (simple) problem as the group's stylized case

Discuss the context of the problem and the main factors underlying it

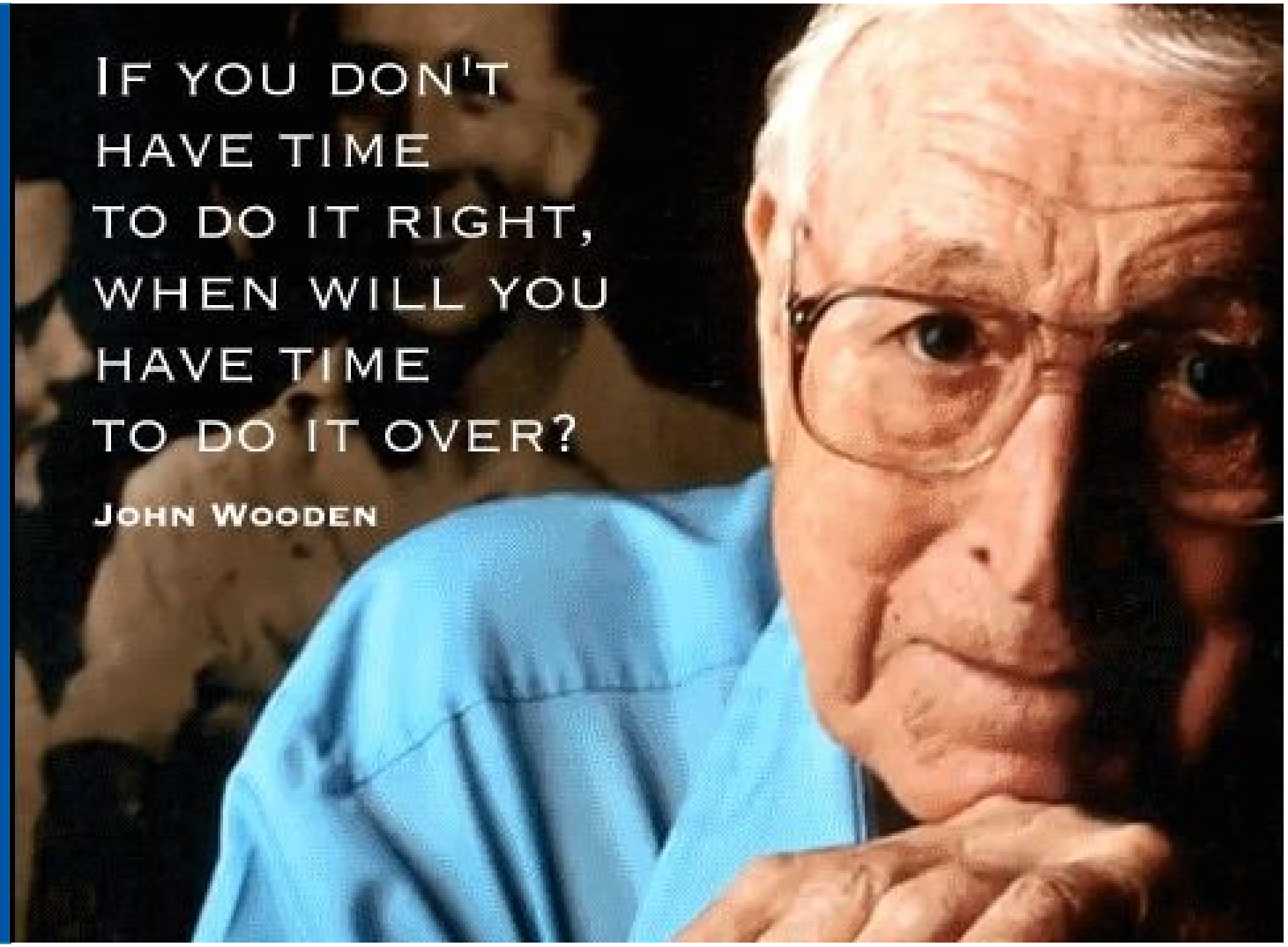
Identify possible projects that can handle it

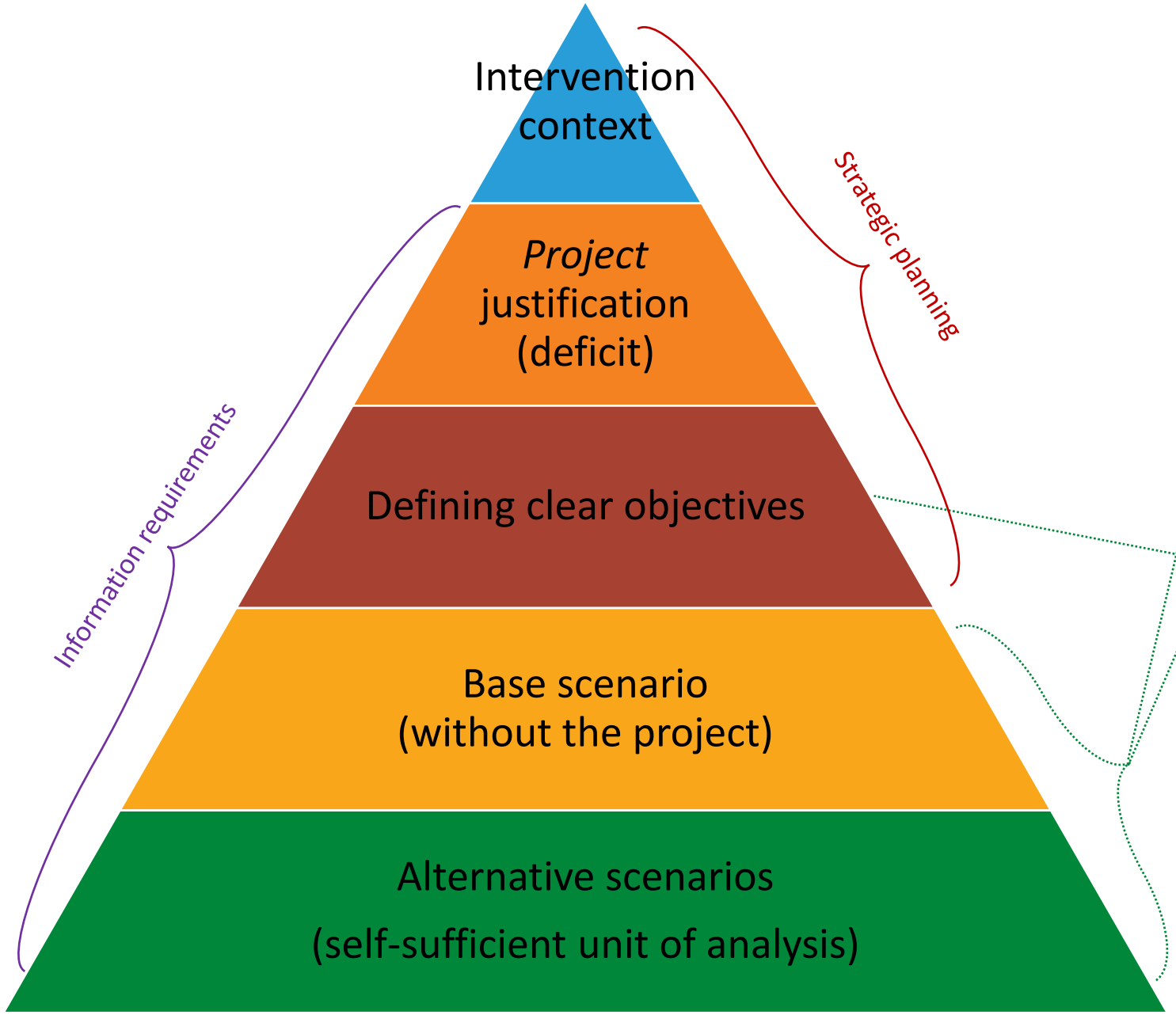
List key decision-making issues for the project(s)

Think about the ways they are regularly addressed

02b

Planning Fundamentals





PROJECT:

A series of works, activities, and services with the very purpose of carrying out a indivisible task, of a precise economic or technical nature, with clearly identified objectives.

(European Commission, 2014)

Context of the intervention

Political, Institutional, and Regulatory Context

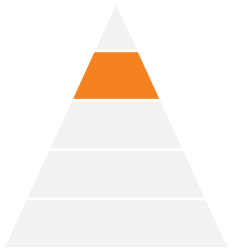
- International agreements and targets (route integration)
- Federal or regional development policies and programs (country integration)
- ASBU stages (APTA, ASUR, FICE, FRTO, NAVS...)

Socio-economic context (volume of service)

- Population growth (densification, tourist region, major construction projects)
- Economic growth and competition (multimodal)
- Technological developments

Project justification:
what is the problem that society needs to address?

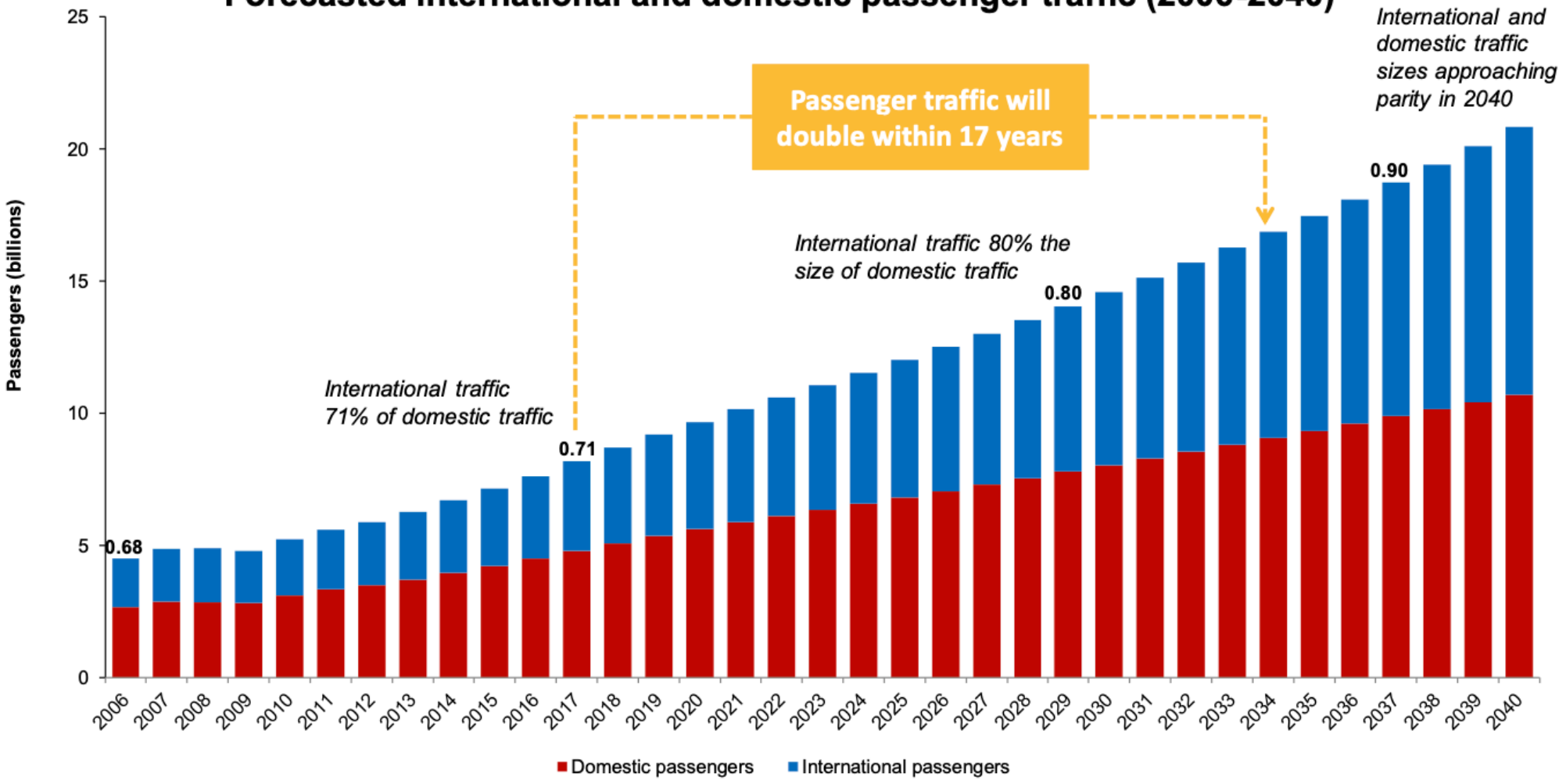
- Society's unsatisfied demands
- Saturation of a service (congestion)
- Unused or underused resources
- Limitations to the development process
- Desire to build local capacity
- Complementing other investments
- Meeting national/regional objectives
- Occurrence of natural disasters



Traffic double within 17 years

AIRPORTS COUNCIL INTERNATIONAL

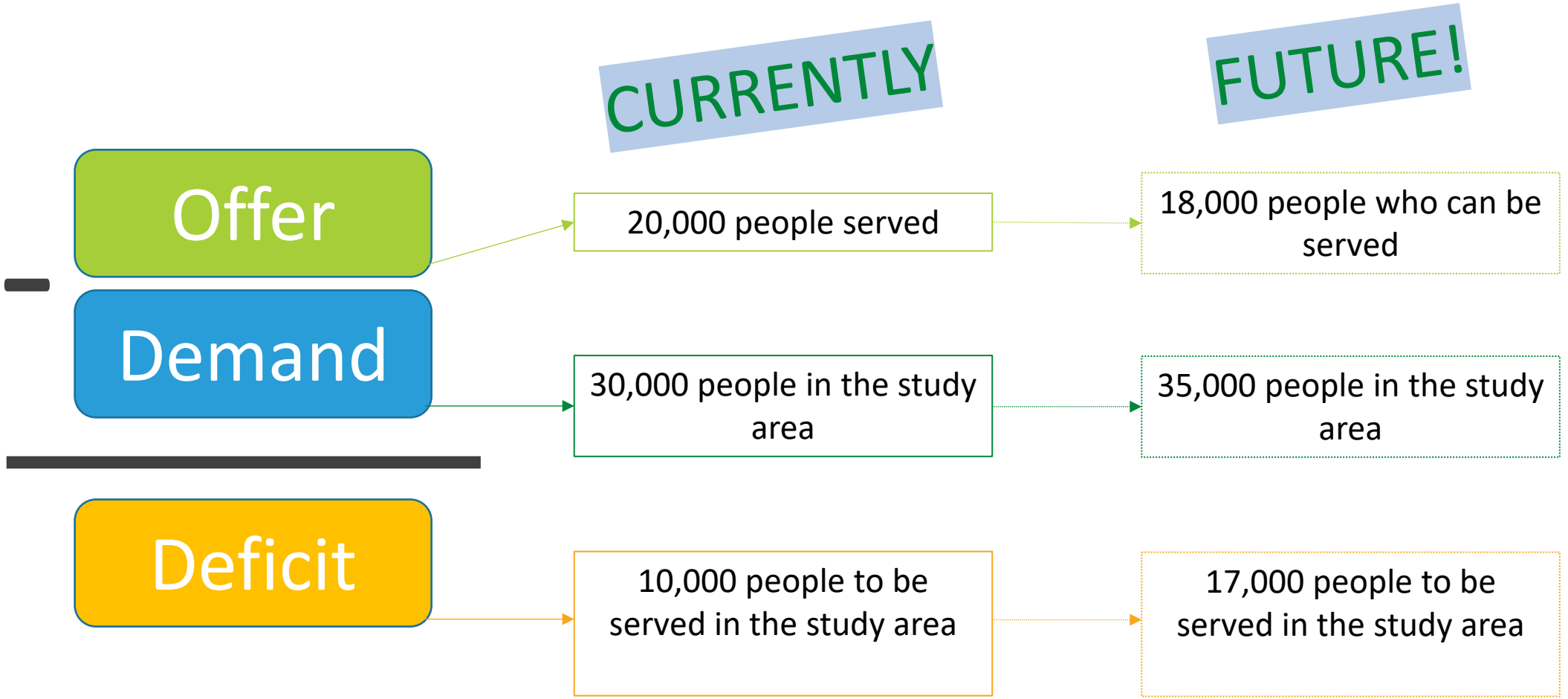
Forecasted international and domestic passenger traffic (2006-2040)



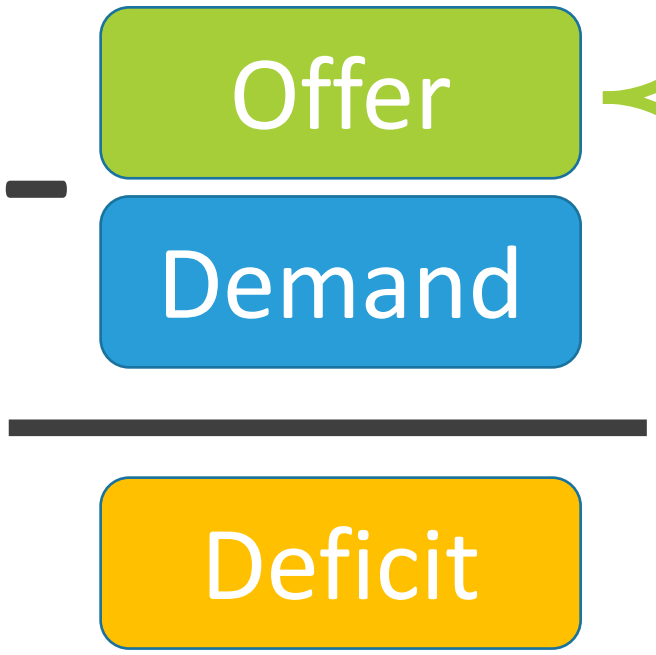
ACI WORLD UPDATE by Mr. Liying Gu (Vice President, Economic Affairs and Research), ACI-NA June 10, 2019

https://aci.aero/airport-advocacy/economics/

Deficit depends on supply and demand projections



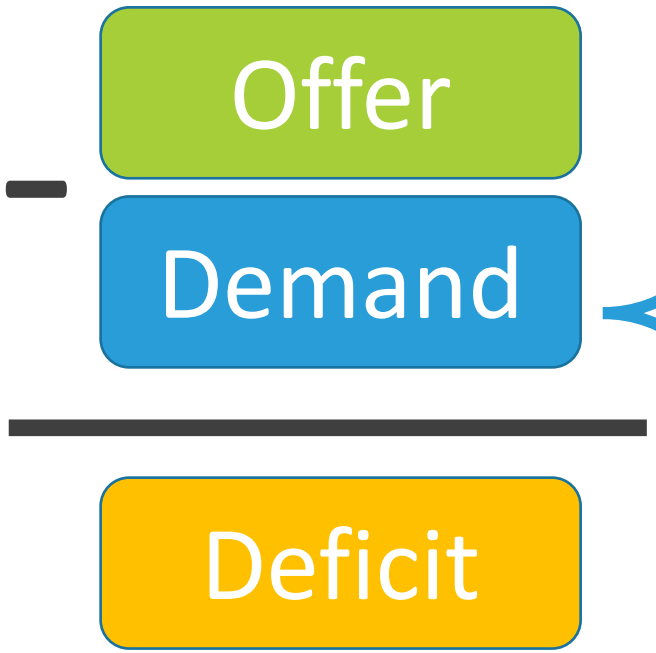
Identifying the problem: Determining the deficit



EXISTING SERVICES

- Existing infrastructure in the area
- Level of service, capacity and quality of the infrastructure service offered (ASBU elements)
- Competition between infrastructures
- Planned and/or recently executed investments that could affect project performance
- Technical characteristics and regulations (safety standards and immigration procedures, for example)
- Current and past service level standards (historical series)
- Statistics related to the use of the service

Identifying the problem: Determining the deficit

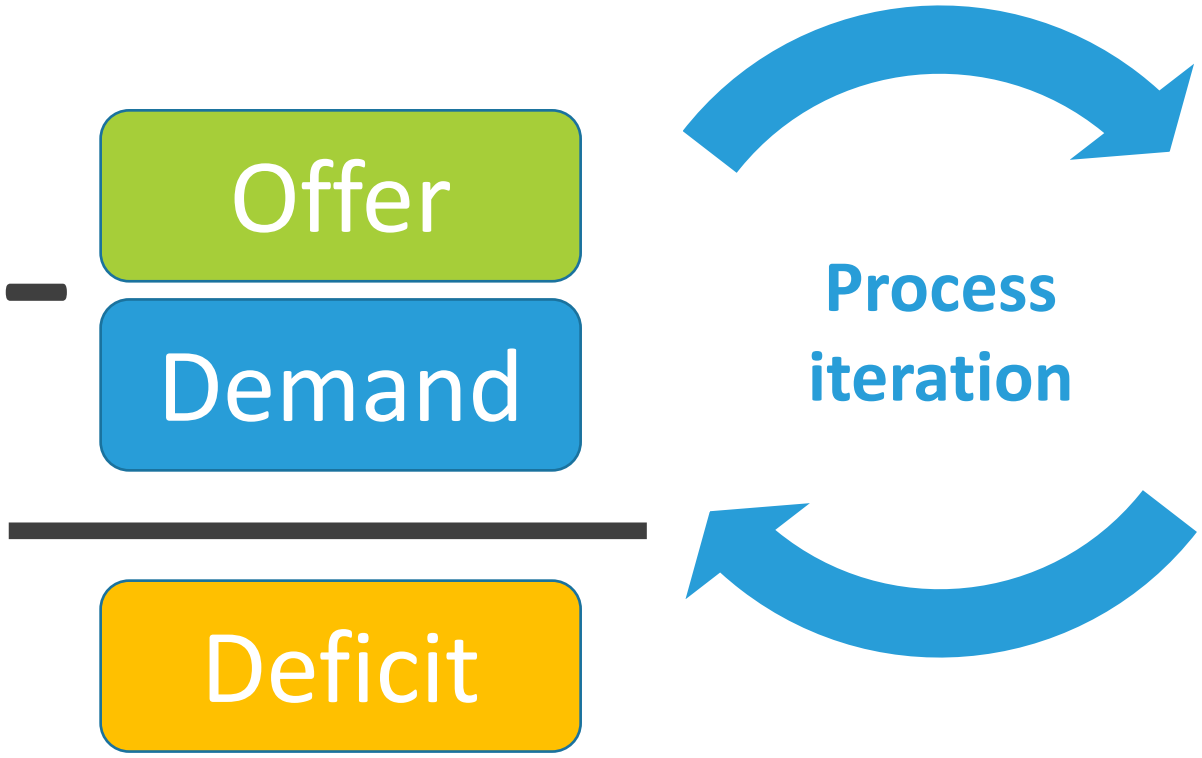


Volume of service required, considering the entire area of influence

- Companies
- Passengers
- Cargo
- Security controls, governance

There's a close relationship between **demand** and the **reference population of** the area of influence: the population served is not necessarily the population that can be served in the future

Identifying the problem: Determining the deficit



- Review the consistency between the diagnosis made and the problem initially proposed
- In the diagnosis, elements may appear that cause adjustments / redefinition of the initial problem

Definition of a clear, precise and achievable objective, derived from the problem (let's be S.M.A.R.T.!)

Specific	... they must be specific and focus on the expected changes ... they should focus on something unique
Measurable	... must be quantifiable and measurable
Achievable	... they must be viable, attainable and credible (consider budget / resources / time / scope / quality)
Relevant	... must be aligned with the strategic context of the sector and the region / territory
Time-bound	... they must clearly state the time horizon they are aiming for

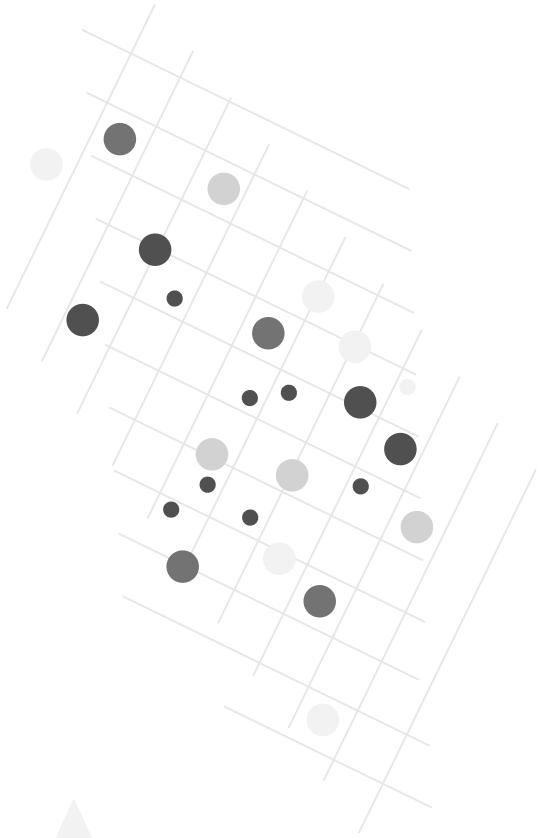
Objectives in the airport sector

Generally, the aim is to deal with growing **congestion**!

One, a few or several possible approaches:

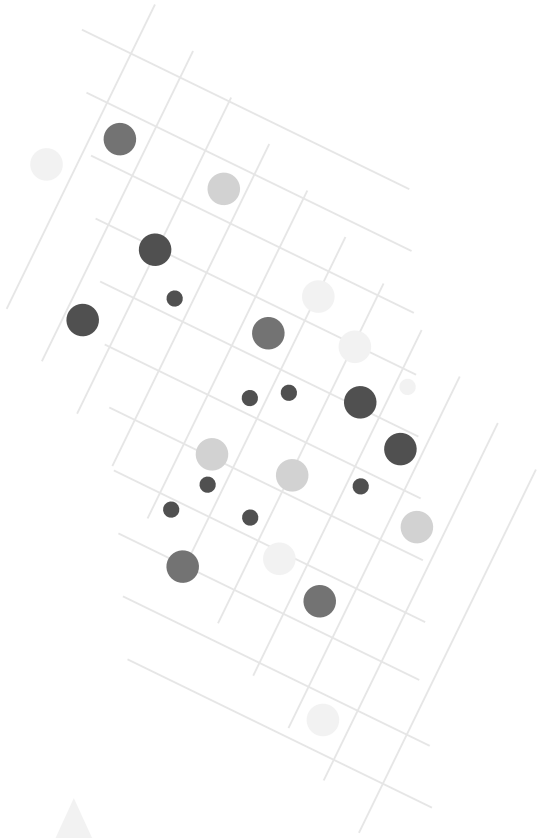
- **Operational improvements (efficiency)**
  - Technology, coordination, and best practices to optimize the use of resources and minimize delays and disruptions (including security and baggage handling)
- **Expansion of infrastructure (supply)**
  - Investment in new infrastructure (expansion of terminals, runways, and aprons)
- **Air Traffic Management (efficiency)**
  - Affect airside operations (intermediate between improvements to operational procedures and airport infrastructure facilities)
- **Demand management**
  - Use of prices, incentives and regulations to influence the behavior of airlines and passengers

Definition of the Base Scenario (*counterfactual*)



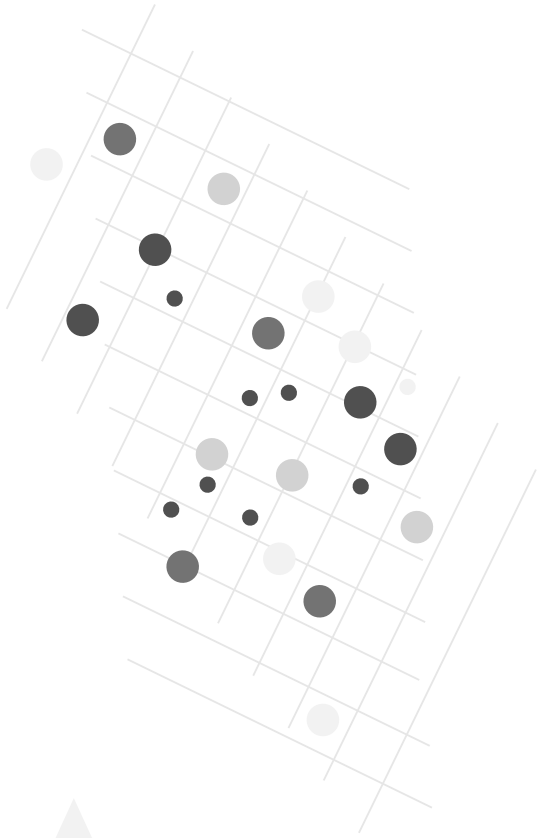
- After defining the problem, its causes and effects, it is necessary to **characterize it** in order to understand the **changes to be promoted by the project** (solution)
- At this stage we identify the **base scenario** => situation that occurs in the absence of the project, i.e. the counterfactual
- For this scenario, **projections** are made of **all the flows of** benefits, costs and externalities related to operations in the project area **during its lifetime**
- It can be ***business as usual*** (absence of services or continuity of current ones) or ***doing the minimum*** (adaptations and improvements that have already been programmed or will need to occur independently of the project's development)

Defining Alternative Scenarios (*project*)



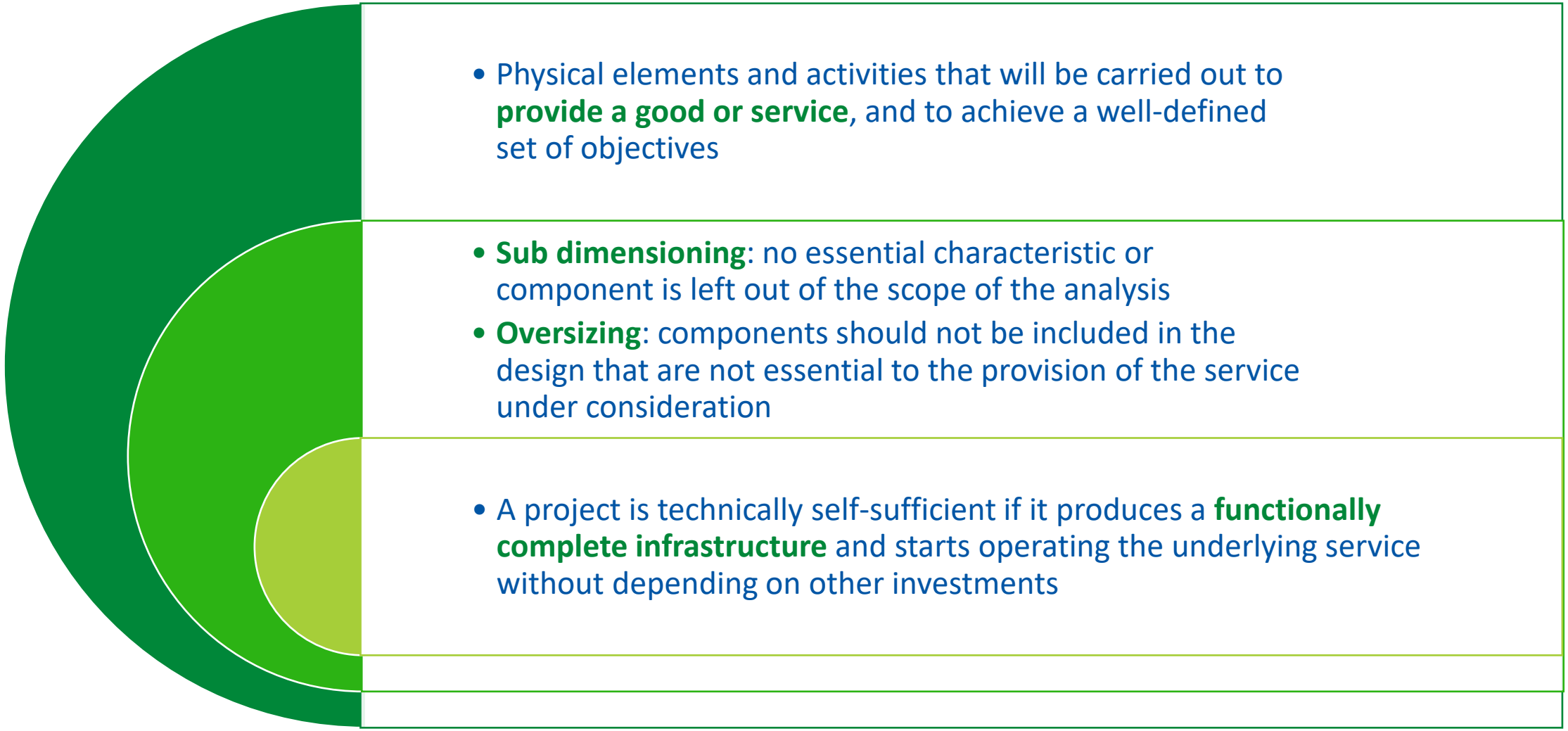
- By deciding on a particular solution, **we give up feasible alternatives** (opportunity cost)
- Therefore, an **adequate list of alternatives** must be considered and prioritized via CBA
- Alternatives must comprise **self-sufficient units of analysis**
- **Strategic analysis of options** is recommended before considering them as possible alternatives

Interaction between planning and risk and uncertainty management



- Capacity expansion decisions are influenced by uncertainties: variability in traffic demand, capacity dynamics and airport business models
- There is a time lag between decisions and the completion of the capacity addition (expensive interventions, with potential conflict and generally slow to be completed)
- One of the solutions is to modularize solutions in order to have adaptability and flexibility over time => ***dynamic adaptive planning***
    - Deployment in the design of various combined intervention options (efficiency, supply, and demand)

Self-sufficient Unit of Analysis



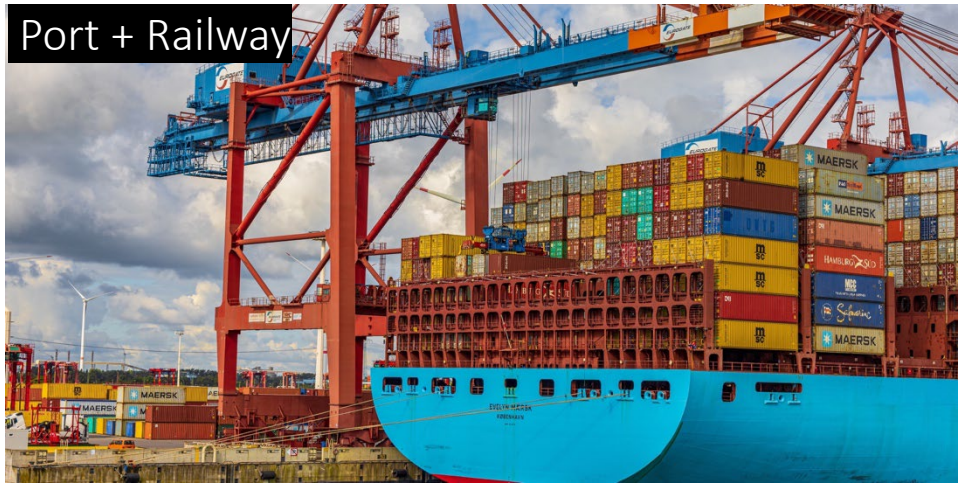
- Physical elements and activities that will be carried out to **provide a good or service**, and to achieve a well-defined set of objectives

- **Sub dimensioning**: no essential characteristic or component is left out of the scope of the analysis
- **Oversizing**: components should not be included in the design that are not essential to the provision of the service under consideration

- A project is technically self-sufficient if it produces a **functionally complete infrastructure** and starts operating the underlying service without depending on other investments

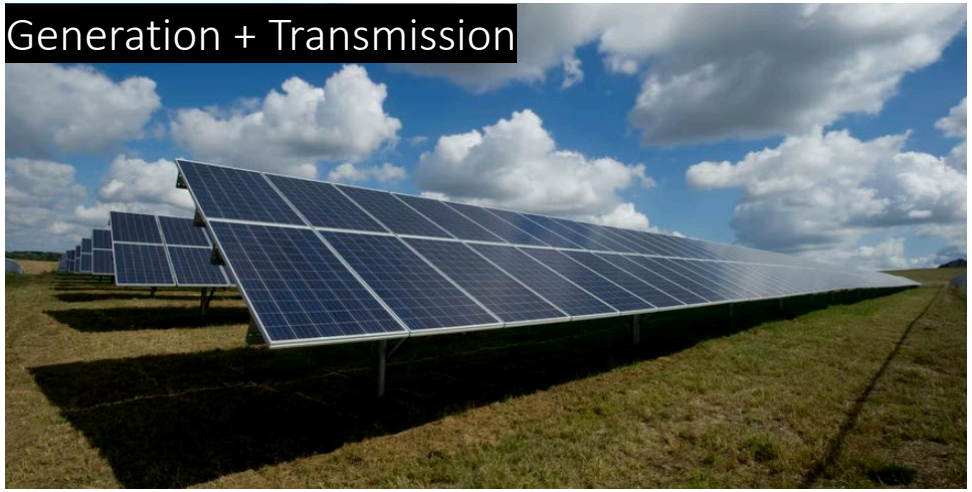
Examples of Self-sufficient Unit of Analysis

Port + Railway



Landfill + Proper road access

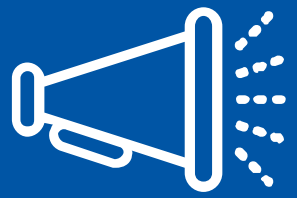
Generation + Transmission



Dam + Irrigation infrastructure

Group Exercise

Stylized case of economic appraisal



Time to present and discuss our findings!

1st task

What problems are we addressing?

Discuss problems in air navigation and airports that need to be addressed

Choose a (simple) problem as the group's stylized case

Discuss the context of the problem and the main factors underlying it

Identify possible projects that can handle it

List key decision-making issues for the project(s)

Think about the ways they are regularly addressed

03

Identifying relevant costs and benefits

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General guidelines for socio-economic evaluation

- **Social opportunity cost**. Benefit of the best alternative. Addresses conflicts of choice (trade-off). Use of the Social Discount Rate (SDR).
- **Microeconomic approach**. Viability is assessed on the incremental promotion generated by the project: difference between the base and project scenarios. Project-specific effects are considered.
- **Assigning a monetary value**. All effects (positive and negative) are considered in their monetary variations, the net result of which is evaluated using viability indicators such as ΔNPSV and ERR
- **Long-term analysis horizon.** There is no clear prescription for the time horizon of CBAs, but it is common to adopt 20 to 30 years (this should reflect the service life of the asset). Projections entail uncertainties that must be dealt with in the risk analysis.

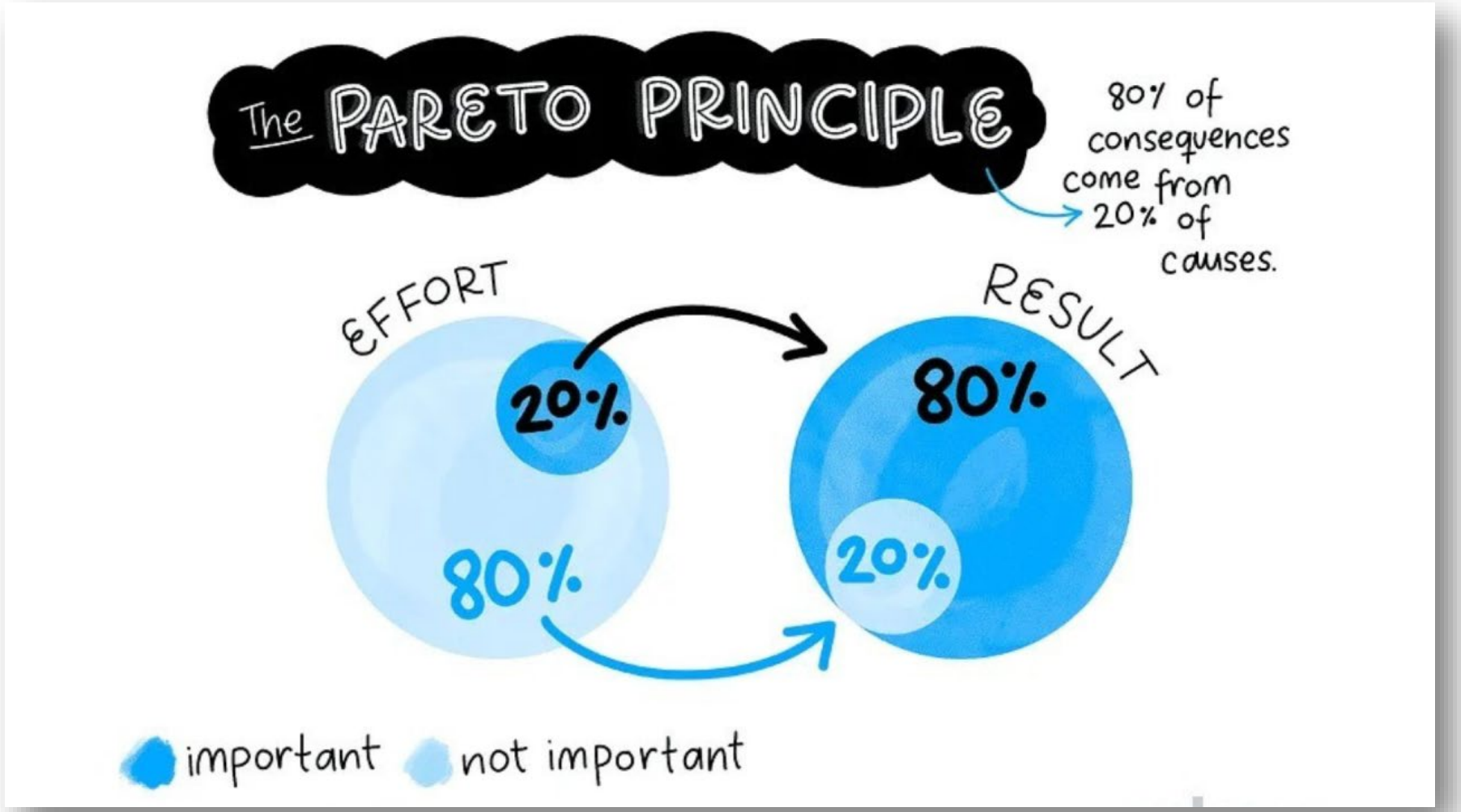
Identifying outcome categories

To establish **what** and **how** counts for the CBA, **all the outcomes of** the project on society must be considered

Outcomes are distributed differently among agents, and can have repercussions in terms of costs, benefits, and/or externalities...

	Directly Involved Agent A	**Directly** Involved Agent *n*	**Indirectly** affected Agent A	**Indirectly** affected Agent *n*
Allocative costs (negative real effects)	○ **Cost**	○ **Cost**	○ **Externality**	○ **Externality**
Allocative benefits (positive real effects)	○ **Benefits**	○ **Benefits**	○ **Externality**	○ **Externality**
Transfers (purely redistributive, neutral effects)	○ **Mere transfer**	○ **Mere transfer**	○ **Mere transfer**	○ **Mere transfer**

Identifying outcome categories



Identifying outcome categories

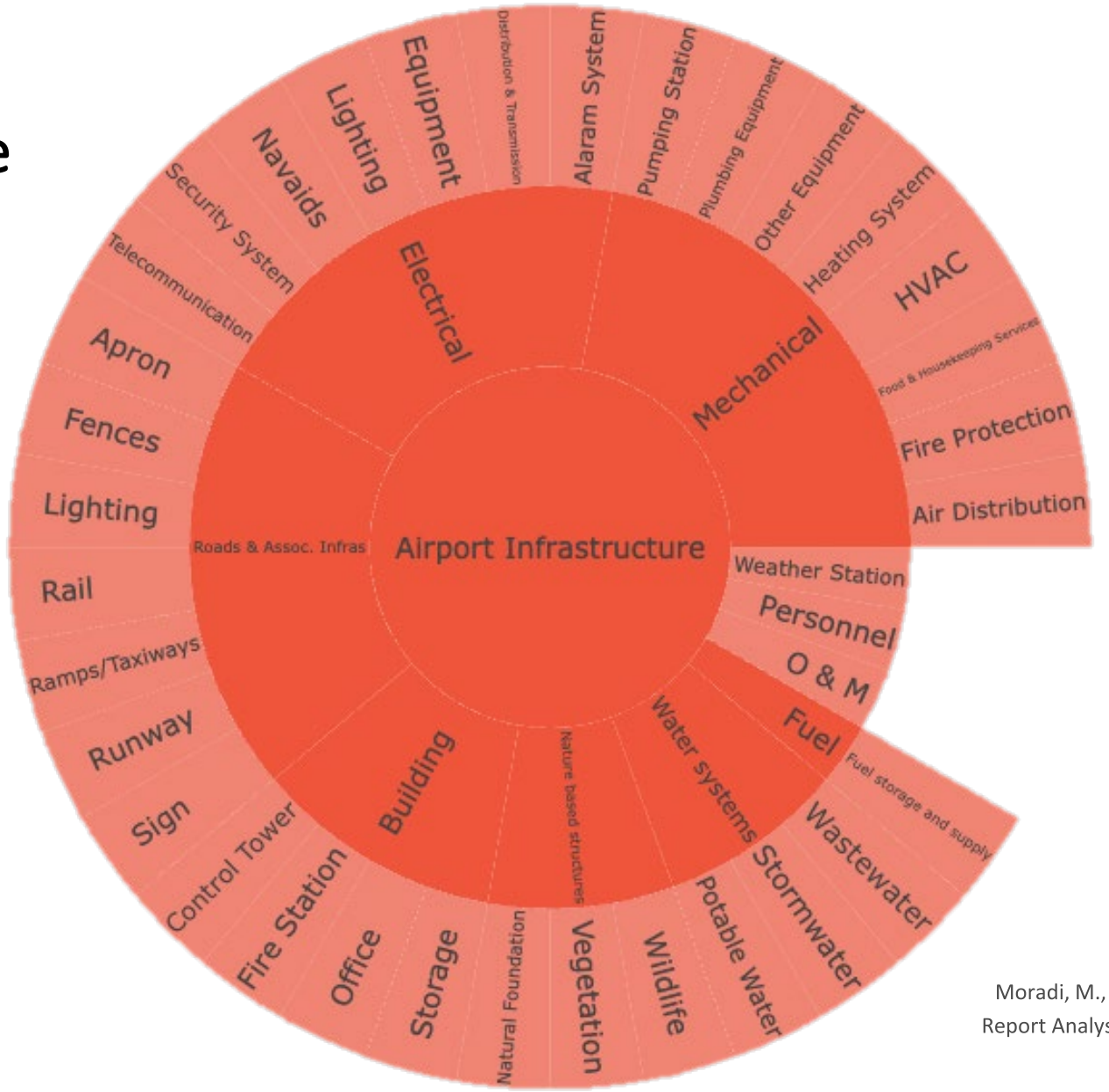
Example of categories (incidence) of costs and benefits of a
Training Program for the Unemployed

	Directly Involved Agent A	Indirectly affected Agent A
Allocative costs (negative real effects)	- Informal jobs that are no longer carried out	- Training costs (per se) - Administration / management costs
Allocative benefits (positive real effects)	- Increased well-being and self-esteem - Increase in income after training (net of tax)	- Possible increase in supply for firms (difficult to measure!) - Tax increase (given the increase in income)
Transfers (purely redistributive, neutral effects)	- Supplementary income during training - Loss of unemployment benefits	- Payment of supplementary income during training - Savings from unpaid unemployment benefits

From key planning issues to information requirements and baseline quantities

What is the problem to be solved/addressed?	**Potential types of benefits and externalities**
What is the demand for the project (population, economic activities)?	**Demand to be met / size of project**
What is the design / engineering solution for each alternative?	**Direct costs: Capex and Opex**
What is the context of the intervention and its potential social and environmental impacts?	**Externalities / stakeholders (indirect)**

Hard airport infrastructure



Moradi, M., Binns, A., Sandink, D., Lapp, D., 2021. PIEVC Report Analysis Utility v1. Toronto/Ottawa: PIEVC Program

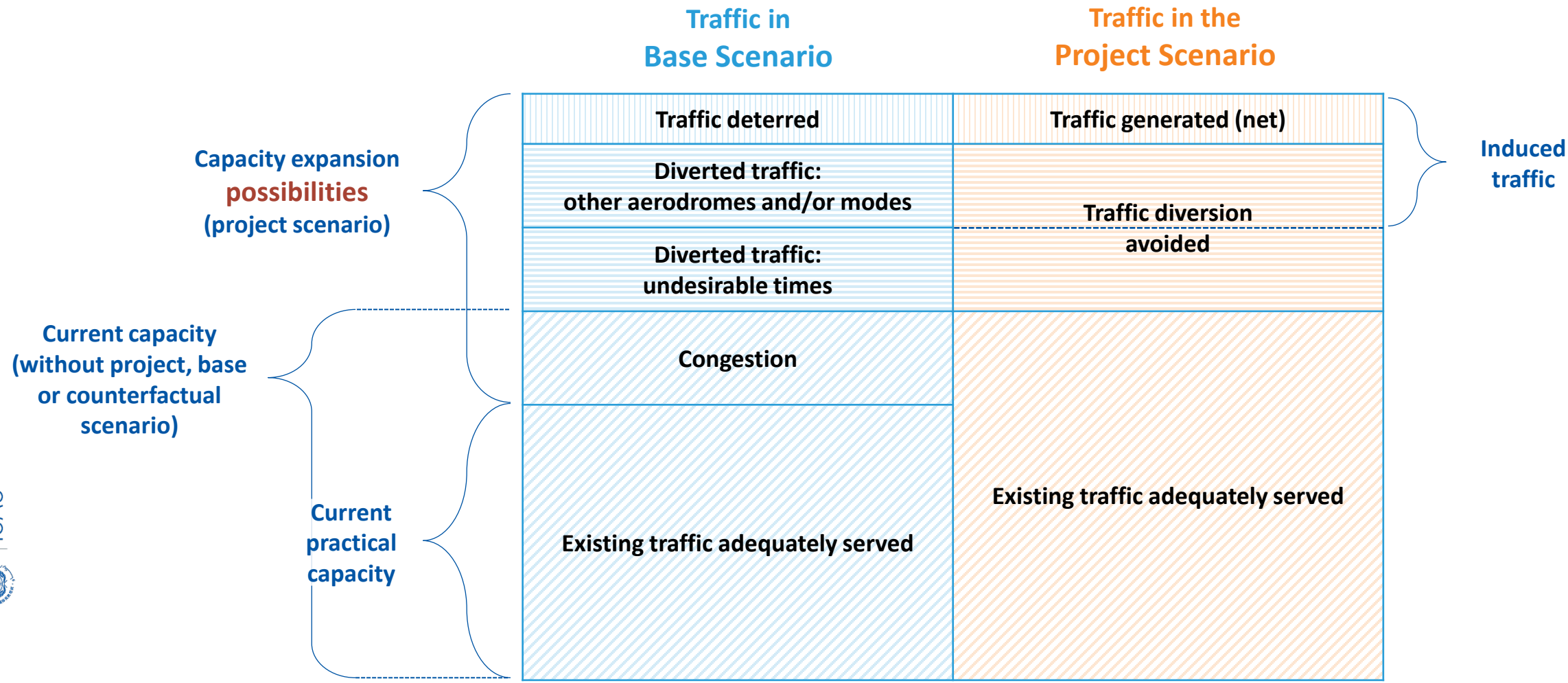
https://pievc.ca

Investments beyond hard infrastructure

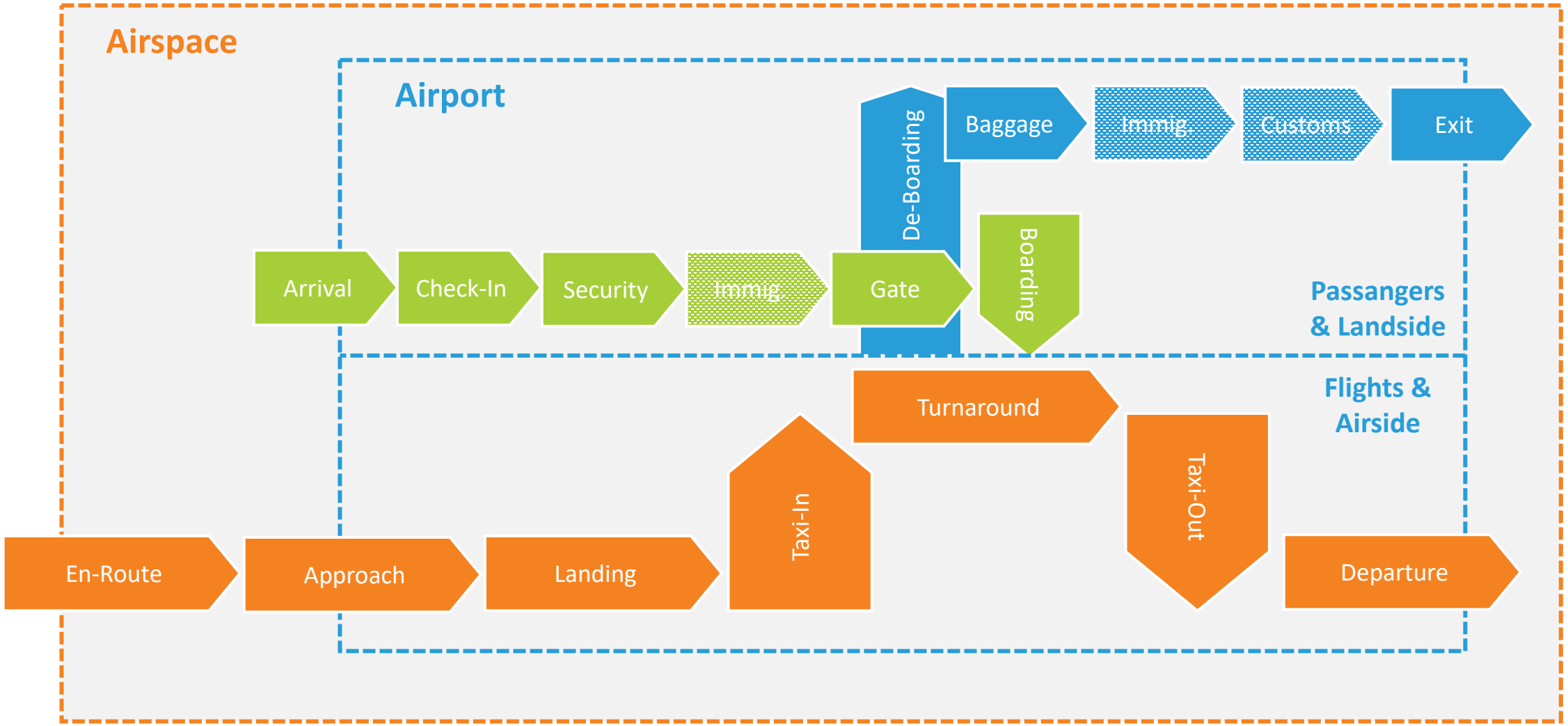
Efficiency gains (Air Traffic Management and/or operational improvements):

- Makes it possible to **increase the frequency of departures** and the **number of routes available**
  - Reduces the difference between a passenger's preferred departure time and the closest actual departure that is acceptable
  - Can reduce overall travel time
  - Can allow the operation of aircraft of different sizes (bigger or smaller)
- **Reduce aircraft processing time**
  - Reduces operating costs for airlines
  - More efficient flights result in lower fuel consumption and pollutant emissions

Capacity expansion and expected traffic



Other interactions (self-sufficient unit of analysis)



04a

Social Costs: Capex & Opex

Photo by Josue Isai Ramos Figueroa on Unsplash

Investment, operating, and maintenance costs (based on market prices)

CAPEX (initial investment, implementation)

- **Includes the capital costs of all fixed assets** (e.g., land, buildings, plant and machinery, equipment, etc.) and **non-fixed assets** (e.g., structuring costs, such as engineering and environmental studies, technical advice, construction supervision, advertising, obtaining permits, implementing environmental plans and programs, environmental compensation, etc.)
- Sometimes **replacement costs** (Repex) are required, such as machinery and/or equipment with a shorter life spam (e.g., electrical equipment, engineering plants, instruments, vehicles, furniture, IT and office equipment, etc.).

Investment, operating and maintenance costs (based on market prices)

OPEX (operation, maintenance and management)

- **Includes:** payroll, materials needed for the maintenance and repair of assets, raw materials, fuel, energy, other consumables in the production process, third-party services, property rental, machinery rental, administrative expenses, insurance costs, quality control, waste disposal, recurring environmental compliance costs, environmental programs, etc.
- **Excludes:** financing costs (e.g., interest payments), which should not be included in the operating costs of the socio-economic evaluation (transfer between agents)
- **Cost projections can be based on historical data, when the profile of operation and maintenance expenses in the past meets minimum quality standards**

Examples
(taken at market prices)

Families of services

- Earthmoving, Paving, Signaling, Drainage...

Costing categories

- Runway, RESA (runway end safety area), taxiway, aircraft yard, SESCINC (emergency services and firefighting), passenger terminal, cargo terminal, vehicle parking, air navigation equipment

Operating costs based on personnel and maintenance

- e.g., MX$ 10.00 / flight handled in personnel
- e.g., MX$ 2.50 / flight handled in maintenance

Shadow price:
conversion to social prices

- Adjusting market prices to **reflect the true social costs** and benefits of goods and services
- Involves recalculating **known market prices** to consider the correction of price distortions (market imperfections) such as taxes, subsidies and quotas
- **Attention:** should a distortion exist to correct for an **externality**, it is already expressed as a social price (or at least closer to it)!
- **Conversion catalogs** are tools used in conjunction with shadow pricing to convert market prices into social prices (they provide conversion factors)
- Should no conversion catalog exist, we only correct **some very relevant** items...

Relevant items that need consideration

Item	Why?	Shadow price method
Labor	Usually a major cost-component Labor markets can be very imperfect in the presence of unions, minimum wages and structural unemployment There can be major differences between skilled and non-skilled; and/or	Shadow wage
Land	Land is always unique (and expansive)! Land can be expropriated by the public sector at a price different from the market value or even given for free to project promoters (but the social cost needs to be considered to account for the opportunity cost)	Market value
Utilities	To boost a given industry/sector or to attract investments, businesses can profit from subsidized prices to purchase electricity, gas and water. Energy prices are also frequently distorted by taxes and externalities	Long-run marginal cost of service (LRMCS)
Imported Commodities	Duties or quotas on imports can be introduced to protect domestic markets (including FUEL), so a border price (conversion factor) must be applied. In its absence, one can estimate efficiency prices or use opportunity costs	Border price

Shadow price:
conversion to social prices

Social price = **Market value** X **Conversion factor (CF)**

CAPEX with unskilled labor: MX$ 6.06 million

CAPEX with unskilled labor: MX$ 10 million

Unskilled Labor Conversion Factor: 0,6064

- CF > 1 : observed market price is **lower than** the social price (subsidy and other distortions that reduce the market price)
- CF < 1 : observed market price is **higher than** the social price (taxes and other distortions that add to the marginal social value of the good and result in a higher market price)

Shadow price:
conversion to social prices

Labor is one of the main non-tradeable item

EXAMPLES IN LATIN AMERICA		
Country	**Category**	**Conv.Factor**
Bolivia	Skilled	1,00
	Semi-skilled	0,43
	Unskilled Rural	0,23
	Unskilled Urban	0,64
Chile	Skilled	0,98
	Unskilled	0,68
	Unskilled	0,62
Colombia	Skilled	1,00
	Unskilled	0,60

Tradeable items

ECONOMIC SECTORS (sample from BR catalog)	FCS
Mineral coal (national)	1,794
Mineral coal (imported)	1,000
Non-metallic minerals	0,960
Oil, natural gas and support services	0,998
Iron ore	0,997
Non-ferrous metal minerals (national)	1,014
Non-ferrous metal minerals (imported)	0,881
Cement	0,908
Cement, plaster and similar articles	0,868
Glass, ceramics and other non-metallic mineral products	0,927
... (128 sectors of activity)	...

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Group Exercise

Stylized case of economic appraisal

Groups of 4-6

Let's mix skills and perspectives!

The task is to develop a ***conceptual*** case study for air navigation projects

Groups will develop it over the course, so stick to the task at hand right now ->

2nd task

What are the costs?

Continuing the group's stylized case:

List and discuss the major costs involved

Discuss the stakeholders involved with each social cost

How far the market price is from its social cost?

Can we estimate the costs?

- project databases...
- price catalogues...

04b

Benefits and Externalities

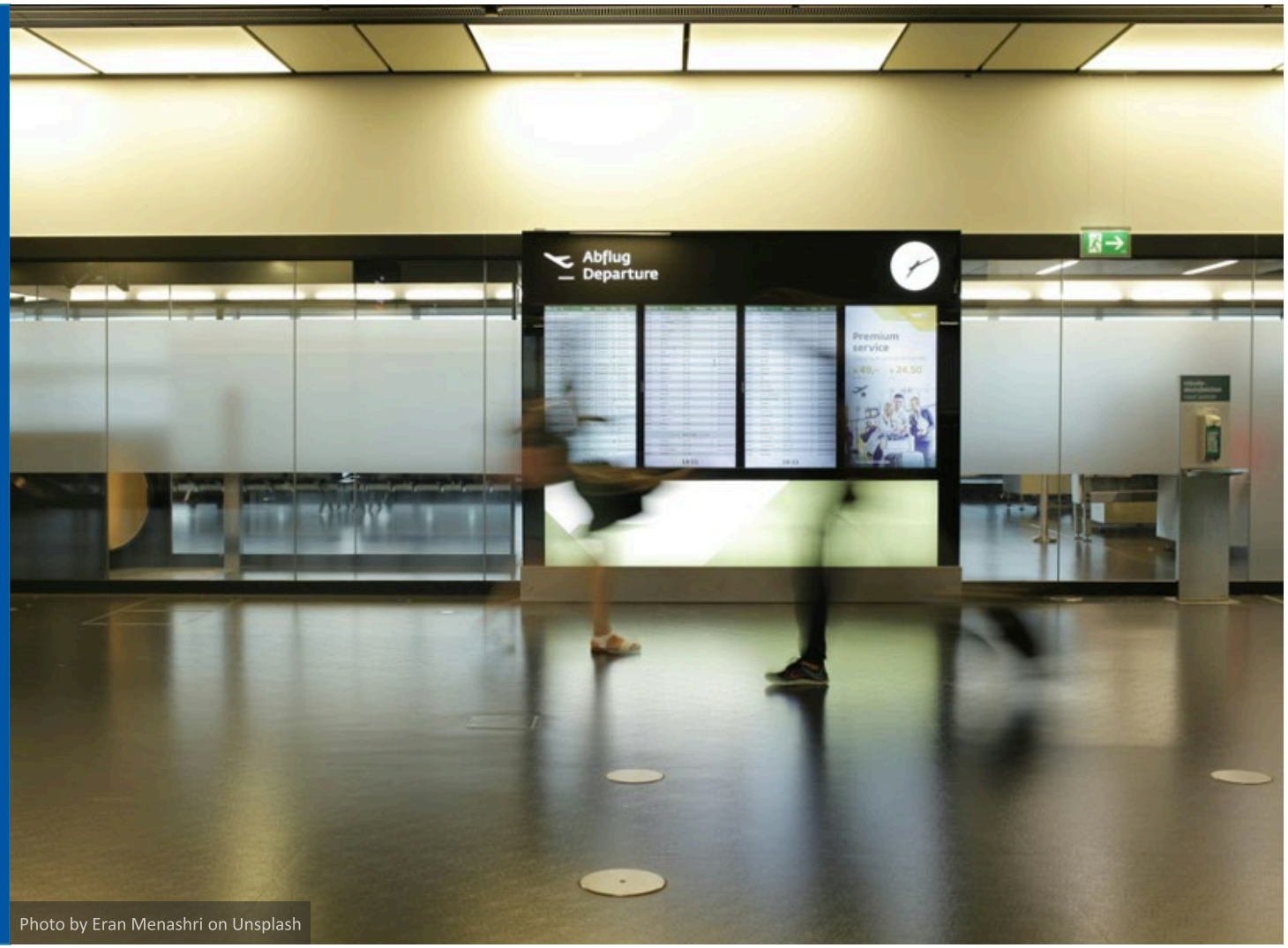

Photo by Eran Menashri on Unsplash

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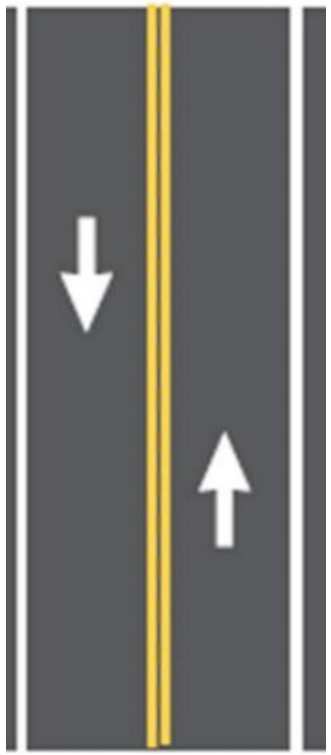
Benefits

Roughly speaking, there are only 3 benefit categories, although there are many types of benefits nested in each of them...

- **Productivity benefits** (increases in the quantity or quality of goods/services and/or reductions in production costs)
  - Directly affect the **quantity** or **quality of** a good or service for households
  - Affect (directly or indirectly) **input costs** for companies
- **Health benefits** (increased longevity, safety or any other improvement in health status)
- **Amenity benefits** (non-market improvements in recreational experiences or quality of life)

BASE SCENARIO



Value of a Statistical Life
$ 5.500.000

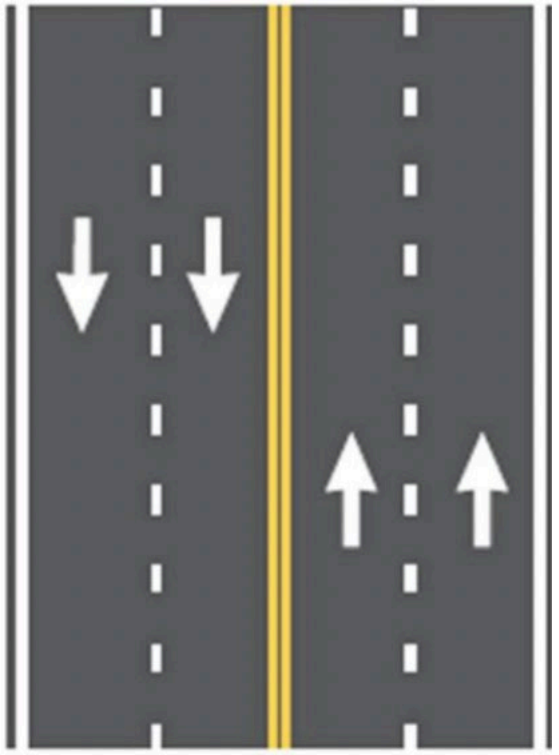
↑

Change in deaths/year
-26

↑

Forecasted deaths/year	
100	74

ALTERNATIVE SCENARIO



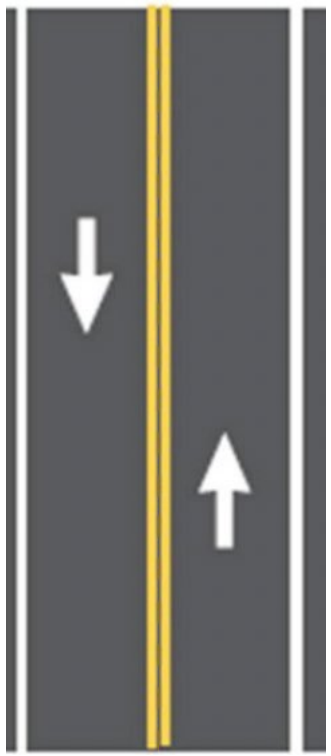
PROJECT BENEFITS

26 x $ 5.500.000
= $143,000,000/year

↑

=	Improved operational safety

BASE SCENARIO



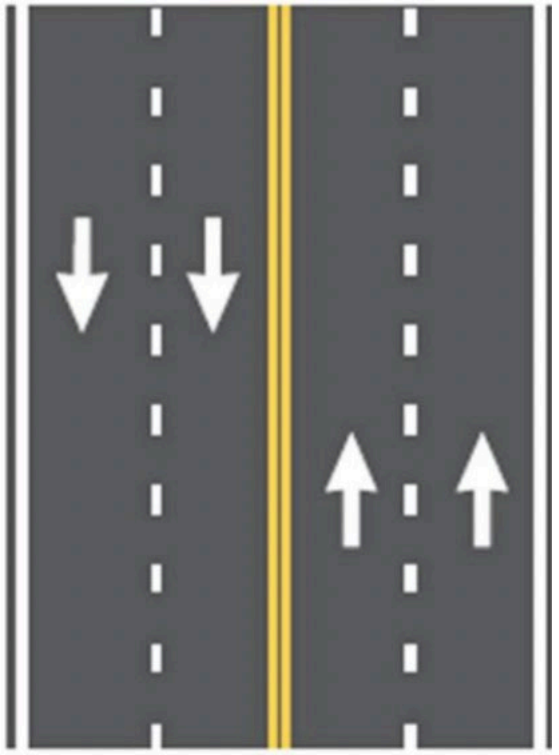
Benefit of $0.40/km

times the number of km

Operating costs

$3.00/km	$2.60/km

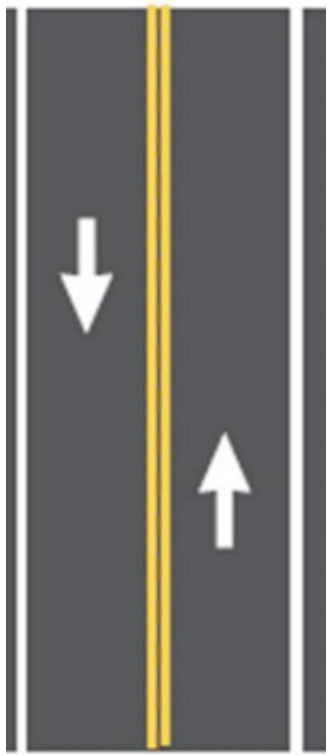
ALTERNATIVE SCENARIO



PROJECT BENEFITS

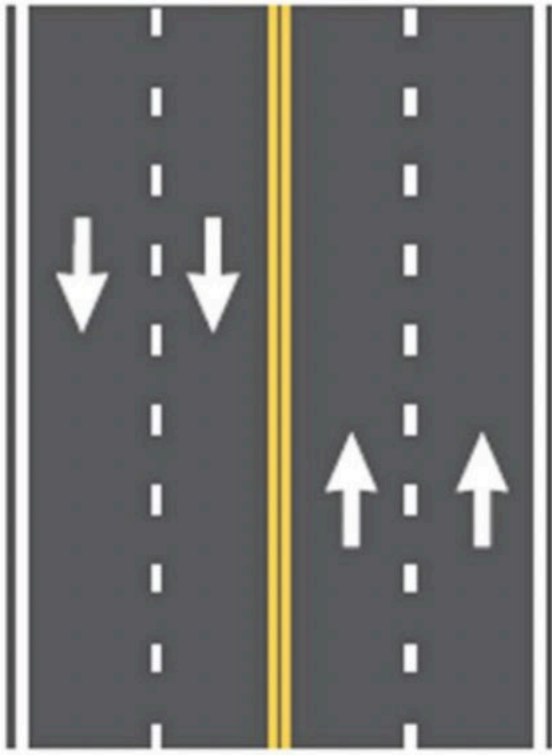
= Reduction in operating costs for transport users

BASE SCENARIO



Average speed	
67 km/h	75 km/h

ALTERNATIVE SCENARIO



PROJECT BENEFITS

=	Reduction in travel time

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There is no market for this third benefit...
although these drivers may be (quite) **willing to pay for** it!

PROJECT BENEFITS

=	Reduction in travel time
=	Reduction in operating costs for transport users
=	Improved operational safety

Adherence of valuation to reality

- **Alignment with beneficiaries' willingness to pay (WTP)**
  - **WTP** is the **maximum monetary value** that people are willing to pay for a certain good or service and **WTR (or WTA)** is the minimum value... to **receive** (or accept) for an inconvenience or loss
    - Empirically **WTR > WTP > LRMCS**
  - WTP **reflects the expected utility** and thus is a measure of well-being that respects people's autonomy and freedom of choice (following John Stuart Mill's "*Harm Principle*")
  - **Capacity to pay** obviously influences WTP, but does not invalidate it: when it is low due to financial constraints, the role of the government is to intervene to ensure that regulatory benefits are accessible, **without forcing individuals to pay more than they are willing or able to pay**
- **Addresses the opportunity cost**
  - Benefits must reflect **the lowest costs of the most feasible alternative** for changing the reality being analyzed

Benefits of expanding air transport

Outcome (benefit or externality)	Beneficiary	Rational	Typical methods for estimating social prices
Change in travel time	**Transport users**	Time spent (ordinarily) by users getting from one point to another Directly affects the efficiency and perceived quality of the transport service Reduced travel times provide more time for other activities (opportunity cost)	Stated preferences Production function Revealed preferences (hedonic pricing)
Change in operating costs	**Transport users and companies**	All vehicle operating costs, including fuel, maintenance, wear and tear and time costs due to traffic management Reductions imply greater economic viability of the transport services, which can make it more affordable for users (opportunity cost of money) and more profitable for companies	Avoided costs (market values)

Benefits of expanding air transport

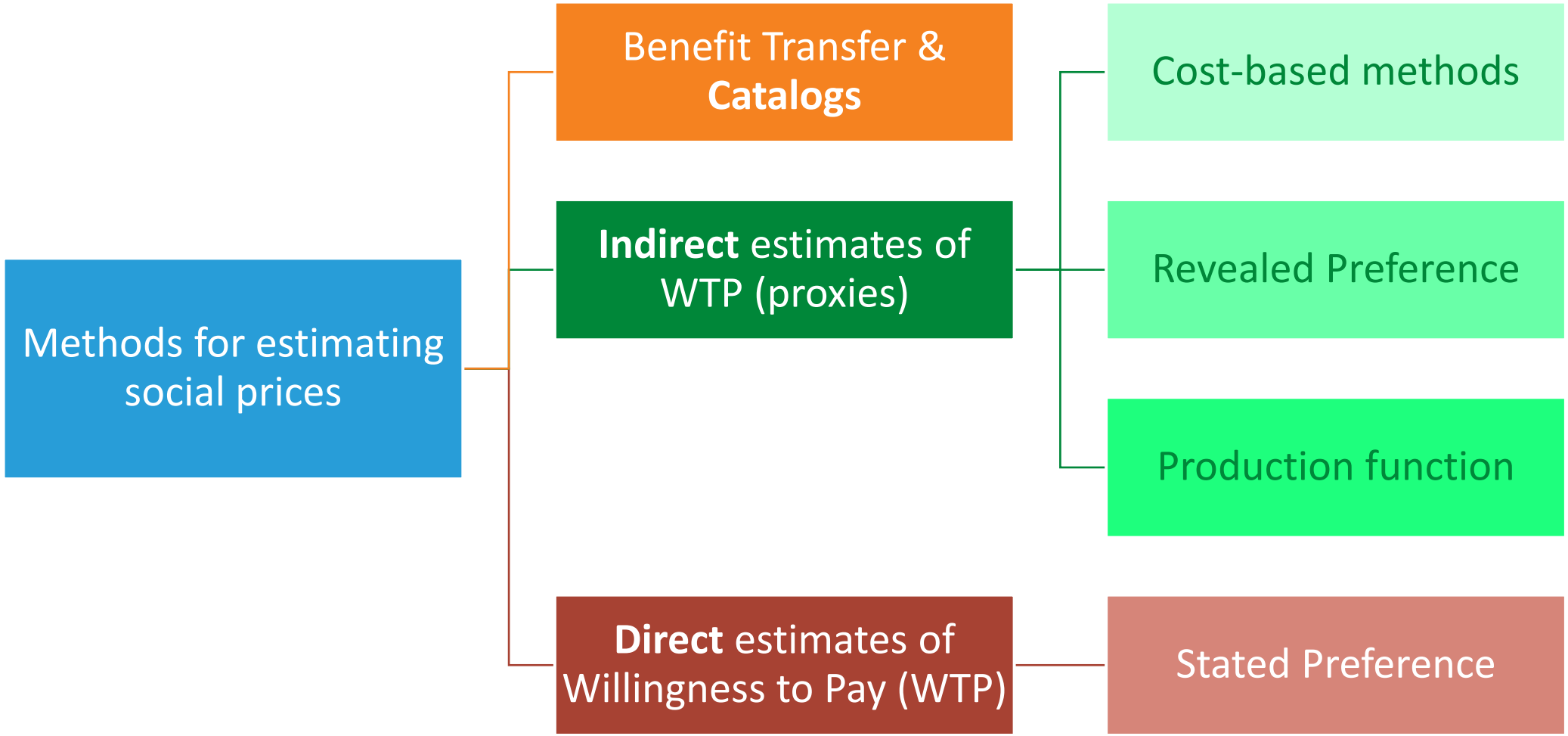
Outcome (benefit or externality)	Beneficiary	Rational	Typical methods for estimating social prices
Change in congestion *(watch out for double counting!)*	**Transport users and companies**	Congestion is excess demand that reduces the fluidity of a movement in a given condition or timeslot Reductions improve traffic flow, reducing travel times for passengers (opportunity cost) and operating costs (for firms and passengers)	See: Change in travel time & Change in operating costs
Change in accidents	**Transport users and society in general**	Frequency and severity of traffic accidents, which may involve deaths, injuries, uninjured and material damage Reductions in accidents avoid costs in terms of deaths, injuries, uninjured and material damage	Statistical value of life Cost of the disease Avoided costs (market values)

Benefits of expanding air transport

Outcome (benefit or externality)	Beneficiary	Rational	Typical methods for estimating social prices
Passenger comfort	**Transport users**	Regardless of the time taken to travel between two points, the level of comfort offered (intangible) has its own willingness to pay (e.g. Airport Lounges)	Stated preferences Revealed preferences (hedonic pricing)
Traffic diversion avoided	**Transport users, airports, companies and commerce**	The expansion of a given airport can avoid the expected loss of traffic to other modes and/or to other airports, increasing traffic and all the associated economic activity	Avoided costs (market values)
Air traffic growth	**Transport users, airports, companies and commerce**	Growth in airport activity shifts the supply curve, resulting in higher revenues At a given airport, growth can be generated or diverted from other locations	Market values

Benefits of expanding air transport

Outcome (benefit or externality)	Beneficiary	Rational	Typical methods for estimating social prices
Change in noise pollution	**Communities close to transport routes**	Noise levels generated by traffic influence the quality of life of people living close by Reductions in noise improve comfort and health (stress and related problems)	Stated preferences Cost of the disease Revealed preferences (hedonic pricing)
Change in air pollution	**Communities close to transport routes**	Vehicle operation emits local pollutants such as Nitrogen Oxide (NOx), Sulphur Dioxide (SO2) and Fine Particulate Matter (PM2.5) Reductions in pollution avoid costs of respiratory diseases and others	Social cost of pollution Cost of the disease
Change in greenhouse gas emissions	**Society in general**	Vehicle operation emits global pollutants, especially Carbon Dioxide (CO2) Reductions in emissions reduce the costs associated with climate change	Social cost of carbon


Methods for estimating social prices
Benefit Transfer & **Catalogs**
Indirect estimates of WTP (proxies)
Direct estimates of Willingness to Pay (WTP)
Cost-based methods
Revealed Preference
Production function
Stated Preference

Use of catalogs

http://www.imt.imt.mx/archivos/Publicaciones/PublicacionTecnica/pt679.pdf

National average of MX$ 237.86 per hour of savings for a cargo vehicle

In Mexico City: MX$ 429.03
In Chiapas: MX$ 108.16

Value of passengers' time, per day:

- by air: R$ 17,745.72
- own vehicle: R$ 259.93
- bus: R$ 170.02

Average value of general cargo: R$ 4,774.13/ton

https://ontl.infrasa.gov.br/planejamento/metodologias/

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Use of catalogs

https://www.eurocontrol.int/sites/default/files/2024-05/eurocontrol-standard-inputs-economic-analyses-ed-10.pdf

Cost of fuel

The cost of fuel used in this document is based on the 2022 average jet fuel price provided by IATA,[3] unless otherwise specified. All conversions are done using the values specified in Table 4.

Currency	Price per barrel	Price per gallon	Price per kg
USD	$ 136	$ 3.2	$ 1.1
EUR	€ 129	€ 3.1	€ 1.0

Table 3: Average jet fuel price in 2022

This section provides the average number of kilograms per minute of fuel burn, by aircraft segment, in different flight phases.

Flight phase	Taxi	En-route	Arrival Management
Scheduled aviation	12.7	51.6	38.6
Regional aircraft	*8.2*	*24.6*	*19.9*
Narrow body aircraft	*11.7*	*40.1*	*35.2*
Wide body aircraft	*25.8*	*113.9*	*85.2*
Business aviation	NA	9.3	7.7
Rotorcraft	NA	8.8	8.8

Table 9: Average fuel burn rates (kg/minute)

Table 16 presents an assessment of the costs of noise for short, medium, and long-haul flights based on an analysis of 33 EU airports.

	Total costs	Average costs			
	€[1]	€ per LTO[1]	€ per pax[2,1]	€ per tonne[1]	€ per km[1]
Short-haul (< 1,500 km)	€ 1bn	€ 305	€ 2.43	€ 10.71	€ 0.55
Medium-haul (1,500 km > 5,000 km)	€ 1bn	€ 305	€ 2.43	€ 10.71	€ 0.33
Long-haul (> 5,000 km)	€ 1bn	€ 305	€ 2.43	€ 10.71	€ 0.01

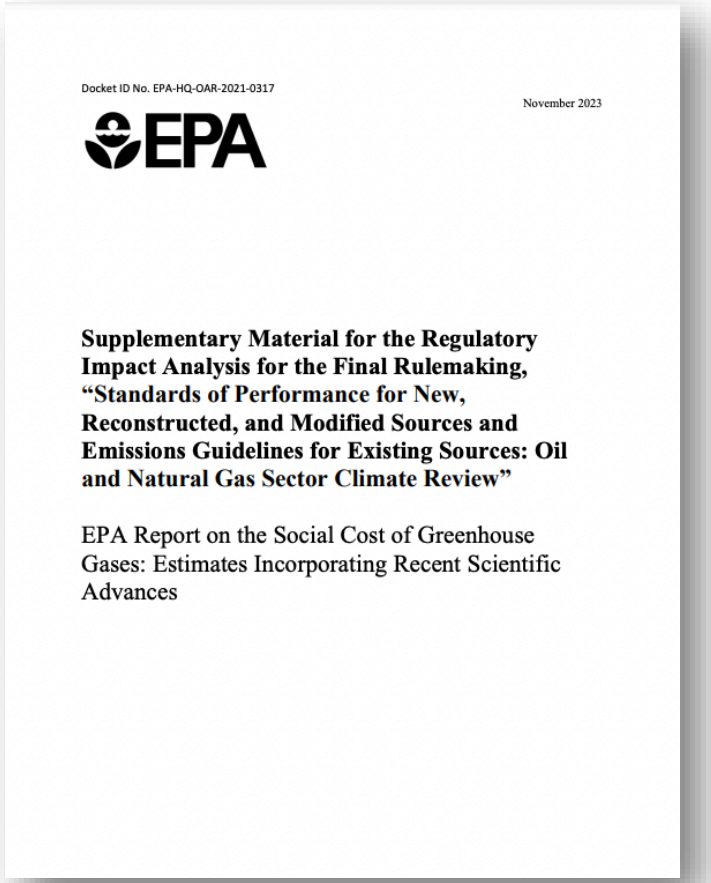
[1]The monetary values originate from Table 36 of the source document and are adjusted from 2016 to 2022 prices

[2]Costs per pax include the complete flight (not only the half-way principle)

Table 16: Total and average costs of noise cost for aviation at 33 selected EU airports[42]

Use of catalogs

USD 120/tonCO2e


Docket ID No. EPA-HQ-OAR-2021-0317

November 2023

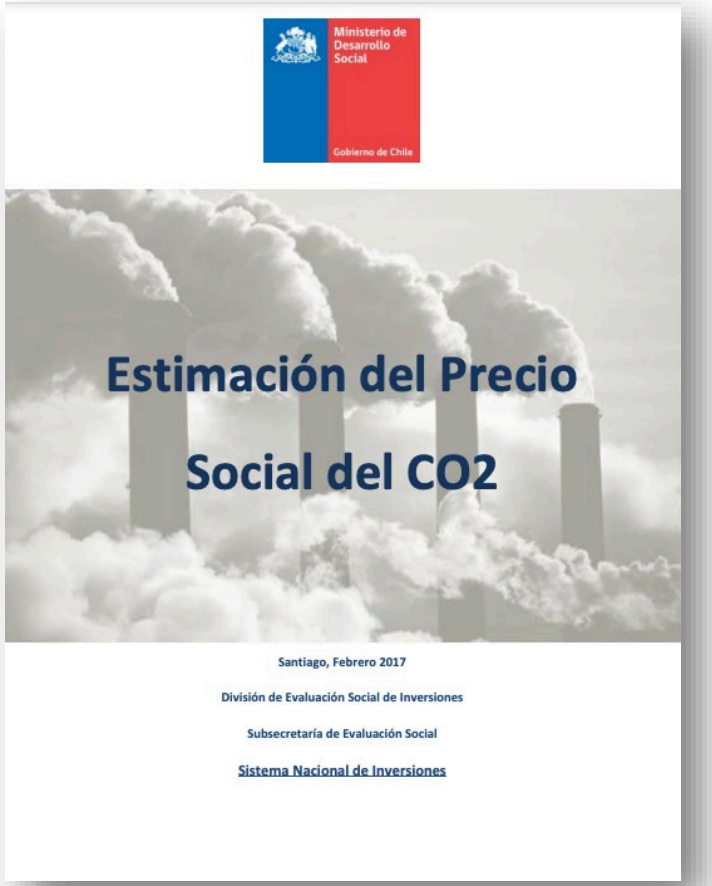
EPA

Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review"

EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances

https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

USD 32,50/tonCO2e


Ministerio de Desarrollo Social

Gobierno de Chile

Estimación del Precio Social del CO2

Santiago, Febrero 2017

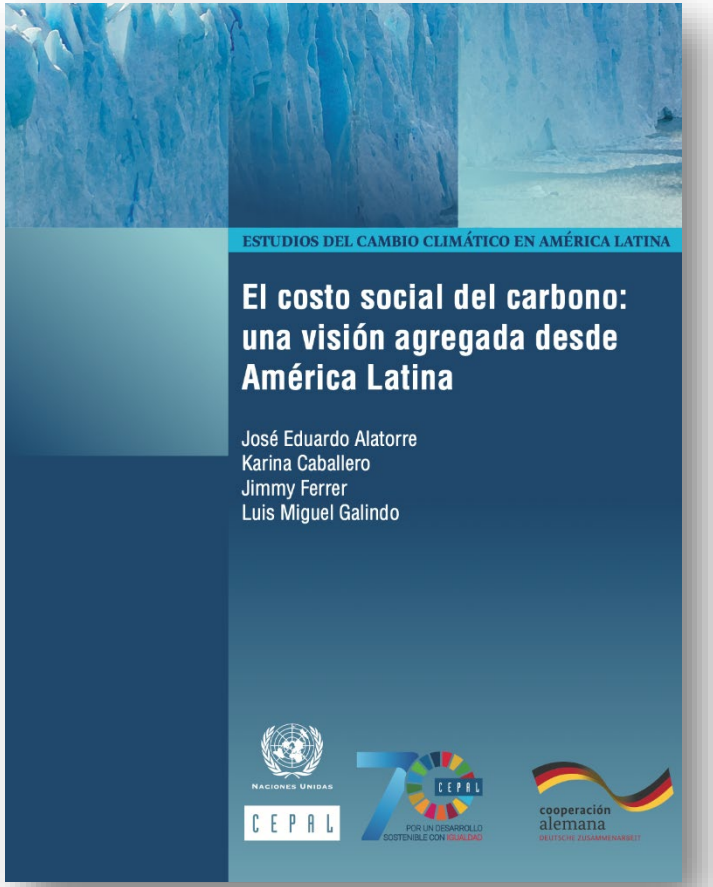
División de Evaluación Social de Inversiones

Subsecretaría de Evaluación Social

Sistema Nacional de Inversiones

https://sni.gob.cl/storage/docs/Precio%20Social%20del%20CO2.pdf

USD 25,83/tonCO2e


ESTUDIOS DEL CAMBIO CLIMÁTICO EN AMÉRICA LATINA

El costo social del carbono: una visión agregada desde América Latina

José Eduardo Alatorre
Karina Caballero
Jimmy Ferrer
Luis Miguel Galindo

NACIONES UNIDAS CEPAL

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cooperación alemana

https://www.cepal.org/es/noticias/nuevo-documento-la-cepal-analiza-valores-costo-social-carbono-la-construccion-politicas

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Table 5-1. Benefit transfer tools and data sources from U.S. government agencies

Name	Agency	Description	Source
Benefit Transfer Toolkit	USGS	Nonmarket valuation database, statistical forecasting models, and recreation activities map	https://sciencebase.usgs.gov/benefit-transfer/
Recreation Use Values	USFS	Estimated recreation use values for 14 recreational categories using the Recreation Use Values Database	https://www.fs.fed.us/pnw/pubs/pnw_gtr957.pdf
Recreation Unit Day Values	USACE	Estimated day use values for recreation by quality tier	https://planning.erdc.dren.mil
Ecosystem Service Benefits	FEMA	Allowable ecosystem service values for Hazard Mitigation Assistance programs by land use type	https://www.fema.gov/sites/default/files/documents/fema_innovative-drought-flood-mitigation-projects.pdf (Table 2-2)
EcoService Models Library	USEPA	Library of ecological production models	https://www.epa.gov/eco-research/ecoservice-models-library
Value of water quality changes meta-analysis	USEPA	Meta-analysis for improvements in water quality based on 51 original studies	https://www.epa.gov/sites/default/files/2015-10/documents/steam-electric_benefit-cost-analysis_09-29-2015.pdf (Appendix H)
BlueValue	NOAA	Database of ecosystem service values focused on coastal areas	https://imagery2.coast.noaa.gov/digitalcoast/tools/gecoserv.html

Table 5-2. Selected benefit transfer tools and data sources from non-U.S. government sources

Name	Organization	Description	Source
Ecosystem Services Value Database (ESVD)	TEEB	Database of ecosystem services values	https://www.esvd.info/
Recreation Use Values Database	Oregon State University	Database of recreation use values in the U.S. and Canada	https://recvaluation.forestry.oregonstate.edu/database
National Ocean Economics Program Non-Market Database	Center for the Blue Economy, Middlebury Institute of International Studies at Monterey	Database of ecosystem service values related to coastal areas	https://oceaneconomics.org/nonmarket/NMsearch2.asp
Environmental Valuation Reference Inventory (EVRI)	Environment and Climate Change Canada (with international partners)	Database of empirical studies on the economic value of environmental assets and human health effects	https://www.evri.ca/en

Benefit Transfer

- Equivalence of the service or good or its functions between the study site and the reference site
- Equivalence of characteristics of the affected population
- Equivalence in the allocation of property rights
- Possibly requires adjustments to the scope, geographical scale and substitutability of the good or service
- Preferably use parameters derived from meta-analyses (*wisdom of the crowd*… or the *theory of canceling errors*!)

FISCHBACH, Jordan R.; BOND, Craig A.; DALYANDER, Soupy; CARRUTHERS, Tim; HEMMERLING, Scott A. Planning and Valuation Methods for Case Study Analysis. Enhancing benefits evaluation for water resources projects: Towards a more comprehensive approach for Nature-based Solutions. The Water Institute of the Gulf. Vicksburg, MS. January 2023. https://ewn.erdc.dren.mil/wp-content/uploads/2023/01/BCA_MethodsReport_Final_01022023.pdf

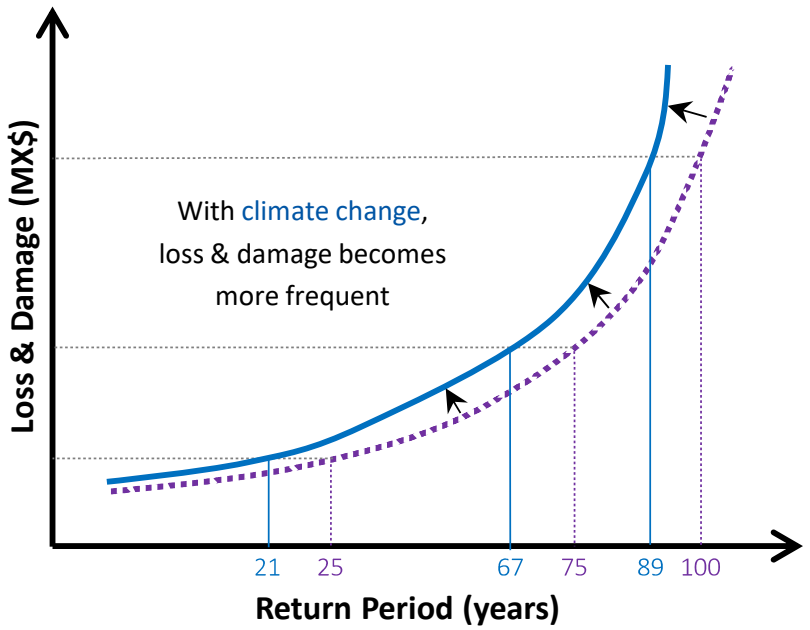
Cost-based methods

- **Damage costs avoided**
  - Economic value is based on the **costs required to prevent or mitigate them**
  - E.g. the cost of traffic fatalities avoided; the economic value of the damage that would occur in the absence of measures to prevent taxiway flooding
- **Replacement cost**
  - Economic value of a good or service (usually environmental - ecosystem services) based on the **market value of another good or service that can replace the functions performed**
  - E.g. the loss of a coastal ecosystem due to the construction of a port, where the value of the ecosystem services lost can be estimated by the cost needed to build an artificial system that offers the same protection against storms and climate regulation
- **Mitigative / avertive expenditures**
  - Economic value of a good or service (usually environmental - ecosystem services) based on the **market value of mitigating or averting the negative effects of its loss**
  - E.g. the cost of a water treatment plant should the quality of the spring water become unsuitable for human consumption

Rational of cost-based methods

- **Surrogate measures of value**, assuming it is easier to estimate costs than benefits per se
- Costs do not have to be part of a "project", but they are hypothetical references of value, i.e. they are a proxy for the benefits
- Their use is common for:
  - dealing with **climate change** (damage avoided), or the cost of "doing nothing"
  - dealing with exposure to pollution and other **health** measures (cost of illness)
- Advantage: easier than WTP/WTR
- Disadvantage: **social preferences** are not accounted for (and could be much higher!)

Illustration of the shift in the probability of damage exceedance curve due to climate change



For example, if a road is flooded by more than 1 meter of water, the cost of repair is around 15% of the initial construction cost...

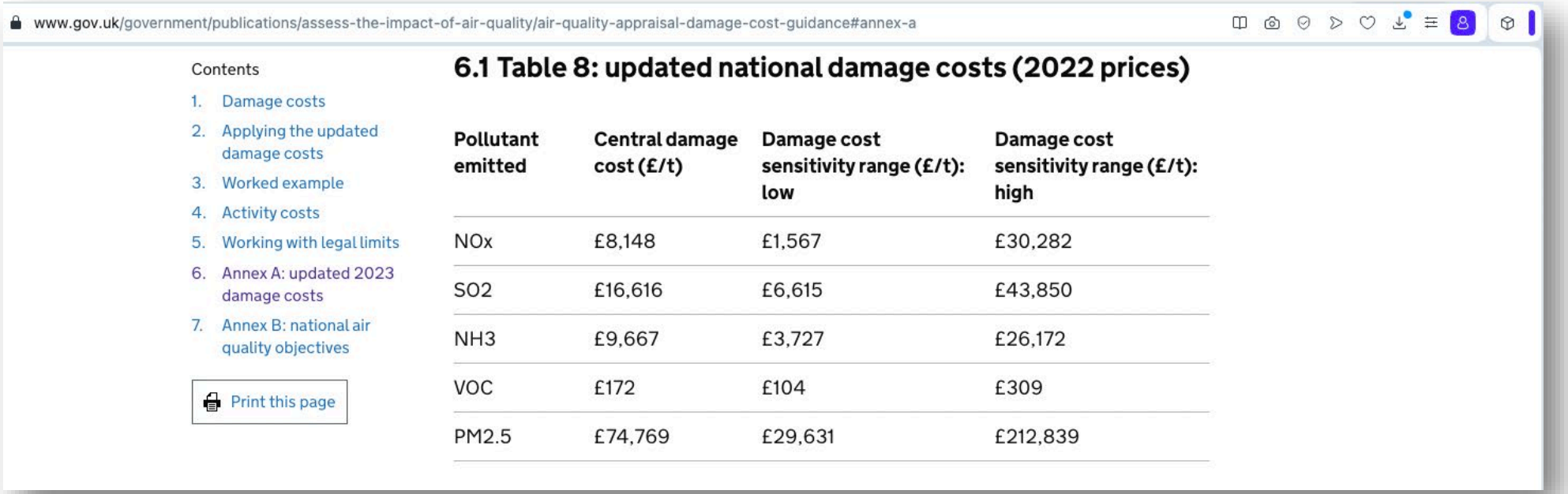
Cost of illness approach

Combines **avoided direct** and **indirect healthcare costs** to produce a proxy for the overall benefit estimate from a society perspective

- **Direct costs**: medical costs necessary for the treatment of a specific disease (e.g. hospitalization, medical supplies, rehabilitation care, diagnostic tests, drug prescriptions, etc.), as well as the statistical cost of life in the case of disease-related deaths
    - Estimated on a case-by-case basis, depending on the type and severity of the disease and the population exposed to it
- **Indirect costs**: value of lost production due to reduced working time because of a specific illness
    - Estimated by multiplying the total absence period (number of days) by the absent worker's gross daily wage
    - For children, people with disabilities and the elderly, working days lost by family members (or to care-takers) can be used as a proxy for the economic value of reducing the risk or duration of illness

Example of local air pollution

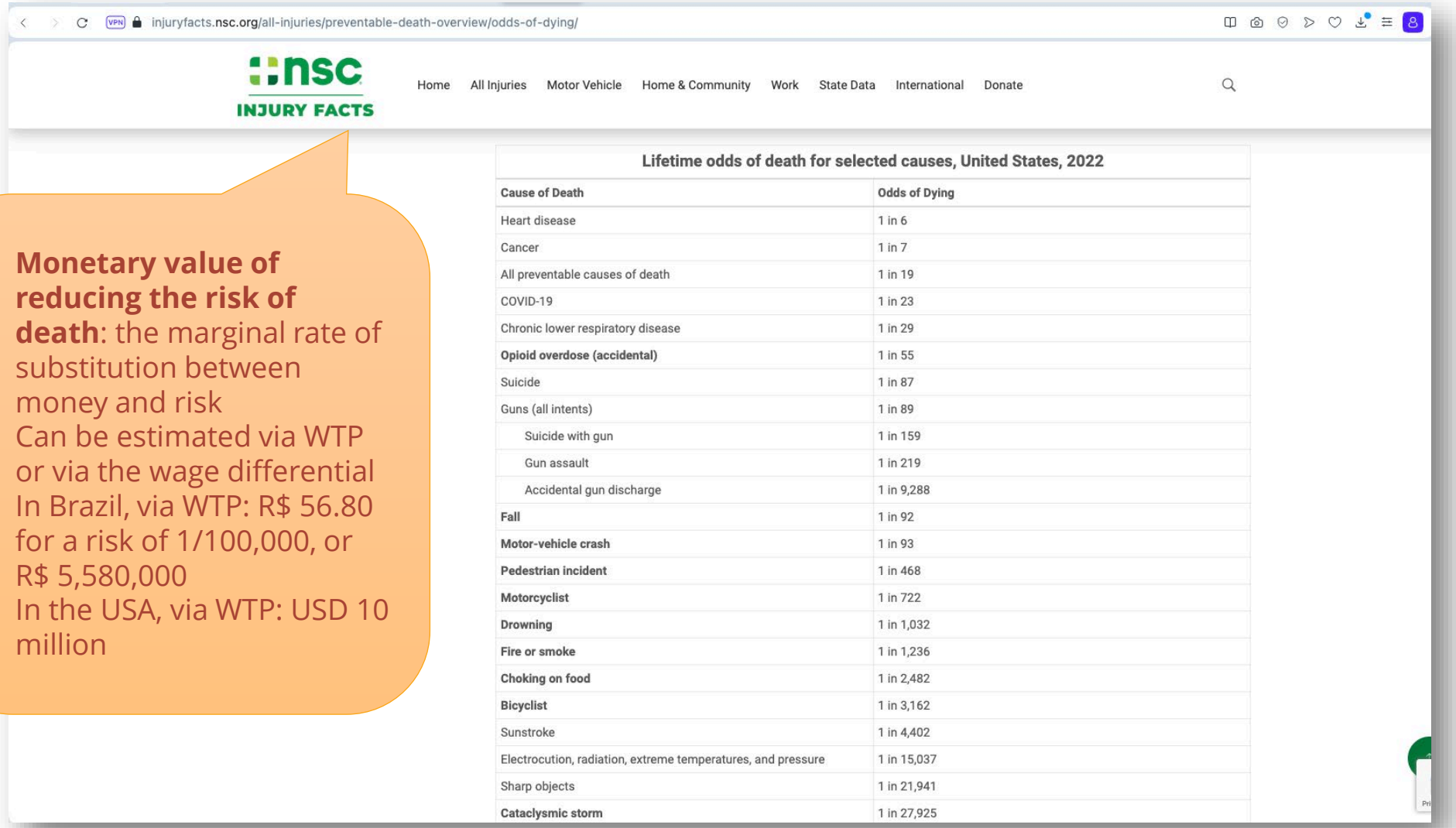
- Nitrogen oxides (NOx) are emitted by aircraft, especially during flight phases close to the airport, such as taxiing, take-off and landing
- Exposure to NOx is **causally** linked to respiratory problems and increased risks of hypertension, triggering myocardial infarction and stroke, both fatal and non-fatal



BONT, J. de, Jaganathan, S., Dahlquist, M., Persson, Å., Stafoggia, M., & Ljungman, P. (2022). Ambient air pollution and cardiovascular diseases: An umbrella review of systematic reviews and meta-analyses. Journal of Internal Medicine, 291(6), 779-800.
HUANGFU, P., & Atkinson, R. (2020). Long-term exposure to NO2 and O3 and all- cause and respiratory mortality: A systematic review and meta-analysis. Environment International, 144, 105998.
FAUSTINI, A., Rapp, R., & Forastiere, F. (2014). Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. European Respiratory Journal, 44(3), 744-756.

Statistical value of life

- **Monetary value of reducing the risk of death**: the marginal rate of substitution between money and risk
- Can be estimated via WTP or via the wage differential
- In Brazil, via WTP: R$ 56.80 for a risk of 1/100,000, or R$ 5,580,000
- In the USA, via WTP: USD 10 million



Lifetime odds of death for selected causes, United States, 2022

Cause of Death	Odds of Dying
Heart disease	1 in 6
Cancer	1 in 7
All preventable causes of death	1 in 19
COVID-19	1 in 23
Chronic lower respiratory disease	1 in 29
Opioid overdose (accidental)	1 in 55
Suicide	1 in 87
Guns (all intents)	1 in 89
Suicide with gun	1 in 159
Gun assault	1 in 219
Accidental gun discharge	1 in 9,288
Fall	1 in 92
Motor-vehicle crash	1 in 93
Pedestrian incident	1 in 468
Motorcyclist	1 in 722
Drowning	1 in 1,032
Fire or smoke	1 in 1,236
Choking on food	1 in 2,482
Bicyclist	1 in 3,162
Sunstroke	1 in 4,402
Electrocution, radiation, extreme temperatures, and pressure	1 in 15,037
Sharp objects	1 in 21,941
Cataclysmic storm	1 in 27,925

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Rational of Revealed Preference Methods

- The **observed behavior of** the population **reveals the underlying value** of certain goods or services
- Based on the theory of consumer behavior: people value the good or service **for its characteristics**, not the good or service itself
- **Variations** in the levels of the characteristics, therefore, can **reveal** the value/utility conferred to the good or service
- It makes it possible to obtain a reasonably accurate **proxy** for **WTP**, since the observed behavior occurs in practice (even if not carried out by the entire affected population)

Photo by Daniel Tha

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Photo by Bornil Amin on Unsplash

Hedonic pricing

- Assumes that **property prices** reflect the value of environmental and welfare attributes (noise being one of them)

Property price = *f* (structural variables, neighborhood characteristics, accessibility, environment)

- The aim is to **statistically isolate the monetary value** of the desirable attribute by analyzing real estate transactions (detailed data on property sales, such as price, size, location, amenities, ...)
- To refine, **interviews** can be conducted with local real estate agents and appraisers!
- **Caution 1**: it is susceptible to the size and openness of the real estate market and the size of the sample (very suitable for urban contexts with dynamic real estate markets)
- **Attention 2**: only captures people's perception of perceived differences (pollution may not have a *link*)

Brazilian example

Instituto Trata Brasil used microdata from a household sample survey (which takes place in capitals and large cities) to uncover the following differences in the value of residential rents:

Properties connected to the sewage system are 16.4% more expensive; the absence of a bathroom reduces the rent by 7.4%; properties with a water supply, sewage system and bathroom are 33% more expensive.

Freitas, F. G. et al. (2018). Benefícios econômicos e sociais da expansão do saneamento no Brasil. Relatório de pesquisa apresentado ao Instituto Trata Brasil. São Paulo: Ex Ante Consultoria Econômica.

Example of Hedonic Pricing

Example with air pollution

In Jakarta, Indonesia, the authors tested the theory that **clean air** has perceived value and thus is a differential for house prices

They analyzed data from properties and their characteristics, along with exposure levels to six pollutants

The results showed that air quality affects property values in the city: value can increase by up to $28 per 1 µg/m³ reduction in sulphur levels

Willingness to pay in developed countries to reduce exposure is higher (between $58 and $328), but even so pollution is priced into the market

Table 1 – Summary of existing hedonic price studies related to air pollution

No [a]	Authors (publication year)	Study location	Pollutant(s)	Sign and significance
1.	Ridker and Henning (1992)	St. Louis, USA	Index of sulfation levels	Negative, significant at 5% level
2.	Wieand (1973)	St. Louis, USA	Suspended particulates	Negative, not ss [b]
			SO_2	Negative, not ss
			SO_3	Positive, not ss
3.	Deyak and Smith (1974)	Some US cities	Suspended particulates.	Negative, ss at 10% level
4.	Smith and Deyak (1975)	85 central US cities	Suspended particulates.	Negative, not ss
5.	Harrison and Rubinfeld (1978)	Boston, US	NO_2	Negative, ss at 1% level
6.	Nelson (1978)	Washington DC, USA	Particulate concentration, summer oxidant concentration	Negative, ss at 5% level
7.	Li and Brown (1980)	Boston, USA	TSP	Negative, not ss
			SO_2	Positive, not ss
8.	Palmquist (1982)	20 US cities	TSP, O_3, NO_2, SO_2	Mixed [c]
9.	Palmquist (1983)	14 US cities	TSP, O_3, NO_2, SO_2, and index of pollution	Mixed [d]
10.	Murdoch and Thayer (1988)	California, USA	Four indicator of visibility	All negative and ss at 10% level
11.	Graves et al. (1988)	California, USA	TSP, visibility	TSP is negative and ss at 5% level, but mixed for visibility
12.	Zabel and Kiel (2000)	4 US cities	NO_2, SO_2, TSP	23 of 80 coefficients are ss at 5% level, 19 of them are negative
13.	Kim et al. (2003)	Seoul, Korea	SO_2	Negative, ss at 5% level
			Nox	Positive not ss
14.	Yang (1996)	Taipei	TSP	Negative, significant at 5% level
15.	Kwak et al. (1996)	Seoul, Korea	TSP	Negative, significant at 5% level

[a] Rows No. 1 to 12 are adopted from Boyle and Kiel (2001).
[b] ss stands for statistically significant.
[c] Negative half the time for TSP and ss in 6 of the 20 TSP coefficients; all negative for NO_2 and ss in 8 of these 18 coefficients; all negative for ozone and ss in 8 of 12 these coefficients; 5 of 20 SO_2 coefficient negative and ss while 1 positive and ss.
[d] For index variable, the estimated coefficient was negative and statistically significant in six of the 14 cities in their study.

Yusuf, A.A. and Resosudarmo, B.P. 2009. Does Clean Air Matter in Developing Countries' Megacities? A Hedonic Price Analysis of the Jakarta Housing Market, Indonesia. Ecological Economics 68 (5): 1398-1407.
https://www.sciencedirect.com/science/article/abs/pii/S0921800908004412

Example of Hedonic Pricing

Impact of aviation noise on real estate prices around Taoyuan International Airport in Taiwan

Based on the hedonic pricing method, the authors find empirical results that point to a significant negative impact on house prices in the noise contour zones of 60-64 dB and ≥65 dB (day-night average sound level)

House price depreciation is approximately USD 2356.02 per dB in the 60-64 dB zone and USD 3622.78 per dB in the ≥65 dB zone

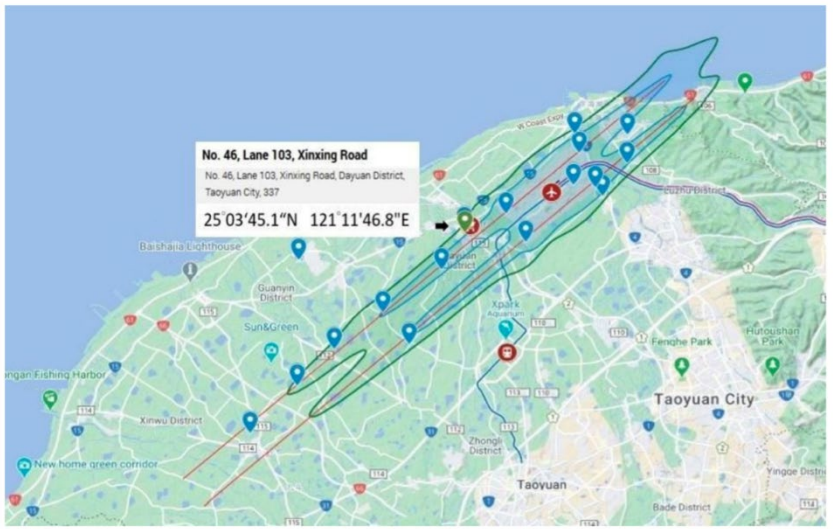

Figure 2. Runway baseline and geographic location map of 18 monitoring stations.

Models tested:

- Semi-Log Model, Inverse Semi-Log Model, **Double-Log Model**

Variables used:

- House characteristics: Total area, age of the house, number of floors, distance from public markets, distance from high-speed train stations, and distance from the airport
- Noise-Related Variables: Estimated value of aviation noise and noise reward fund

Tsao, H.-C., & Lu, C.-J. (2022). Assessing the Impact of Aviation Noise on Housing Prices Using New Estimated Noise Value: The Case of Taiwan Taoyuan International Airport. Sustainability, 14(1713). https://doi.org/10.3390/su14031713

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Other methods of revealed preferences

They all follow the same logic...

Photo by Daniel Tha

Defensive / preventive behavior

- Installing double-glazed windows to prevent noise

Travel costs

- Amount spent (money and time) to access a given site

Self-provisioning or self-supply

- Water supply by water tanker
- Installation and operation of septic tanks

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Production Function Method

- **Used when the good or service (non-market) being valued is a production input of another good or service with market value**
- Changes in the quantity or quality of the good or service being valued result in changes to the final product, affecting the social surplus that is traded in markets (shadow price)

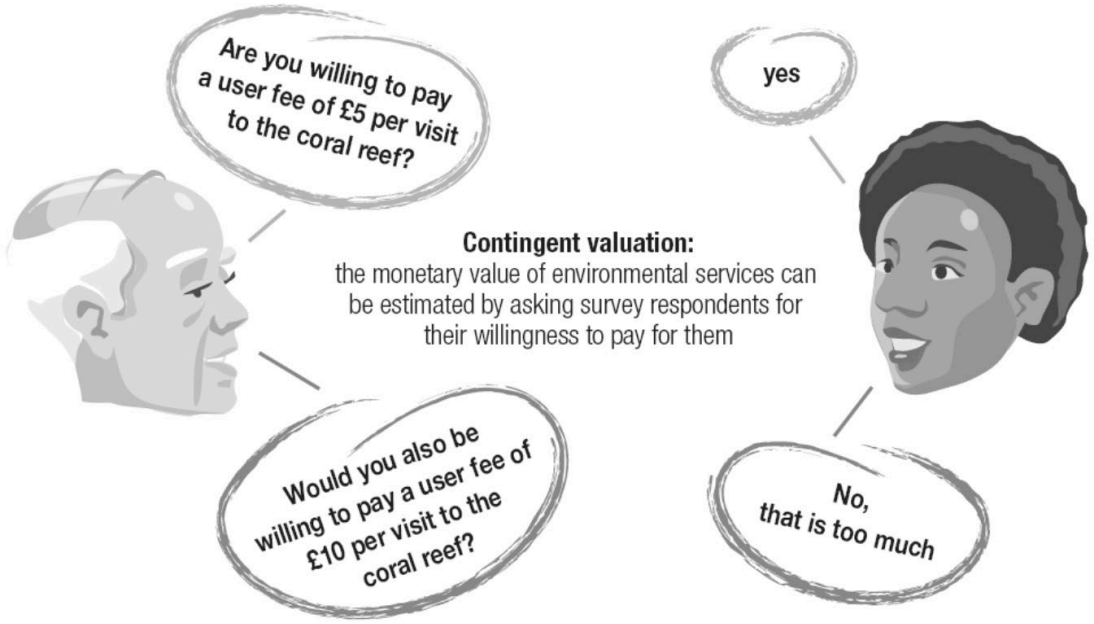
  Δ quality or price for consumers: Δ consumer surplus

  Δ productivity or the cost to producers: Δ producer surplus
- Estimated with **observable market data** (converted to social prices)
- Typically used to value **ecosystem services** such as water quality and/or availability, soil quality, climate regulation, pollination, biological control, erosion control, etc.
- Can be applied to **time savings**, since time is a scarce input that affects production
- Requires market data for production inputs and the final good or service
- **Warning: does not account for social preferences, so may return underestimated values**

Stated preference methods

Contingent Valuation Method

- Questionnaires are applied directly to the benefited/affected population (sample size must have statistical validity!)
- Questionnaires (or choice cards) should take into account behaviors; clearly present the contingent scenario; start with a low price and go up until the point of rejection
- Statistical techniques establish the relationship between the characteristics of the good or service and the preference of a group of individuals



- It is important that the questionnaire clearly addresses the hypothetical form of payment (WTP or WTR) and its frequency

An example in the road sector

Economic evaluation of road traffic noise in China, using the contingent valuation method (CVM)

In Tianjin, a fast-growing city, twelve residential areas were selected, categorized by noise exposure levels

1,800 questionnaires were administered (1,604 valid)

Questionnaire had 4 sections:

- Environmental Attitude: an icebreaker with an attitude towards environmental pollution in the city
- Exposure Response: on the general nuisance caused by road traffic noise
- Willingness to pay (WTP): how much they would be willing to pay to reduce noise
- Socio-economic control information

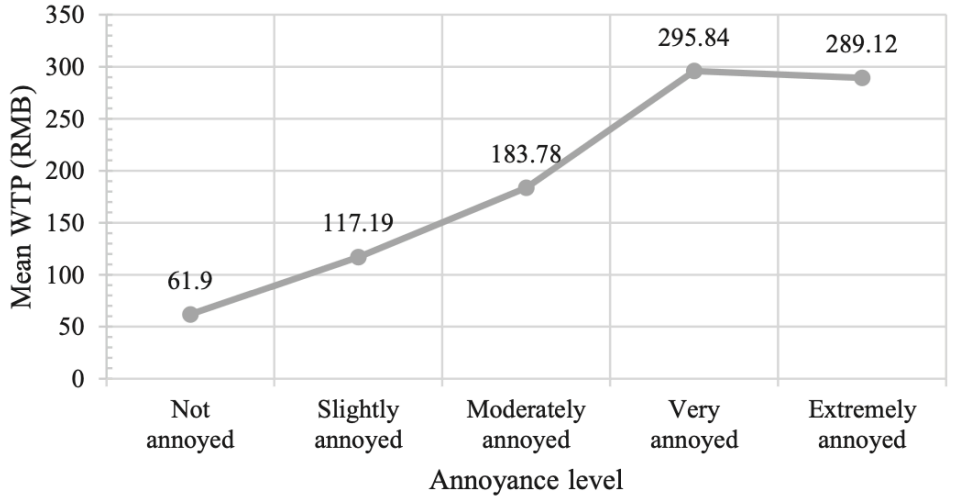


Fig. 4. The mean WTP for different annoyance levels.

WTP is significantly influenced by residents' level of annoyance, age, income and previously used noise prevention methods

Ma, H., Wen, M., Xu, L., & Zhang, Z. (2021). Contingent valuation of road traffic noise: A case study in China. School of Architecture, Tianjin University.

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An example in aviation

Valuing the environmental externalities of noise and air pollution at Bangkok's Suvarnabhumi Airport

Stated preference choice method was used to determine the willingness to pay (WTP) of local residents (206 interviews) and air passengers (400 passengers) to reduce these externalities

Results (Multinomial Logit Model (MNL)) show that residents place a higher value on reducing aircraft noise, with a WTP of USD 104.76 per year to halve noise levels, while passengers show a USD 70.63 WTP

In terms of air pollution, passengers are willing to pay more (USD 151.18 per year) compared to residents (USD 86.52)

Table 1 – Experimental Design Attributes

Attributes	Levels
Aircraft Noise	25%, 50% less noise As now 25%, 50% more noise
Aircraft Engine Emissions	25%,50% less air pollution As now 25%, 50% more air pollution
Carbon offsetting	Yes/No
Air fare/ Airport Impact Relief Scheme or payment	Increased by 300, 700, 1100, 1500 Baht As now Reduced by 300, 700, 1100, 1500 Baht

Figure1- Choice Card Example – Residents

Attribute	OPTION A	OPTION B	OPTION C
Aircraft are	25% louder	50% quieter	As now
Aircraft engines produce	25% less air pollution	25% more air pollution	As now
Carbon offsetting	Yes	Yes	No
Airport Impact Relief Scheme	You would pay 1,500 baht/month	You would pay 1,100 baht/month	No payment/ compensation
I would choose	A	B	C

Cheramakara, N., Bristow, A., Budd, L., & Zanni, A. (2014). Stated choice valuation of aircraft noise and other environmental externalities at Bangkok Suvarnabhumi Airport. Loughborough University, United Kingdom.

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Watch out for cognitive biases!

Analysis of the WTP to reduce noise and air pollution from transportation in the region of Navarra, Spain, sought to identify methodological problems in the valuation process, such as hypothetical bias, correlation effect and sequence effect

It used a contingent valuation experiment (CVM) and an economic experiment with real incentives, in which 50 individuals took part, divided into two groups of 25

Participants were exposed to two valuation sequences to observe different behavioral biases

Hypothetical Bias: WTP was higher in hypothetical scenarios compared to scenarios with real monetary incentives

Correlation effect: WTP for pollution mitigation is close to that established for noise reduction

Sequence effect: mixed evidence was found, with the effect being present only in the contingent valuation survey part

Summary:

Cognitive biases affect economic valuation in stated preference studies!

Denant-Boemont, L., Faulin, J., Hammiche, S., & Serrano-Hernandez, A. (2021). Valuations of Transport Nuisances and Cognitive Biases: A Survey Laboratory Experiment in the Pyrenees Region. Springer Nature Switzerland AG. https://link.springer.com/article/10.1007/s10666-021-09773-7?fromPaywallRec=false

Wider economic impacts (WEIs)

- WEIs: Wider effects (2nd order), induced effects and indirect effects
- **The application of social prices to costs and benefits, in addition to the monetization of externalities, already accounts for the main impacts on well-being**
- Consequently, **wider economic impacts should - generally - not be included in the CBA**, because in reasonably efficient markets, they are irrelevant in terms of general equilibrium
    - Adding such effects usually results in double counting
- Two of them can be considered in projects that promote **structural changes in competitiveness**, or that affect **inefficient secondary markets:**
    - Effects on the labor market : indirect effects on the region's productivity from behavioral changes related to labor supply
    - Agglomeration effects : productivity gains resulting from an increase in the density of economic activity, as a result of the combined effect of various reductions in transaction costs

Group Exercise

Stylized case of economic appraisal

Groups of 4-6

Let's mix skills and perspectives!

The task is to develop a ***conceptual*** case study for air navigation projects

Groups will develop it over the course, so stick to the task at hand right now ->

3rd task

What are the benefits and externalities?

Continuing the group's stylized case:

List and discuss the major benefits and externalities involved

Discuss the stakeholders involved with each benefit

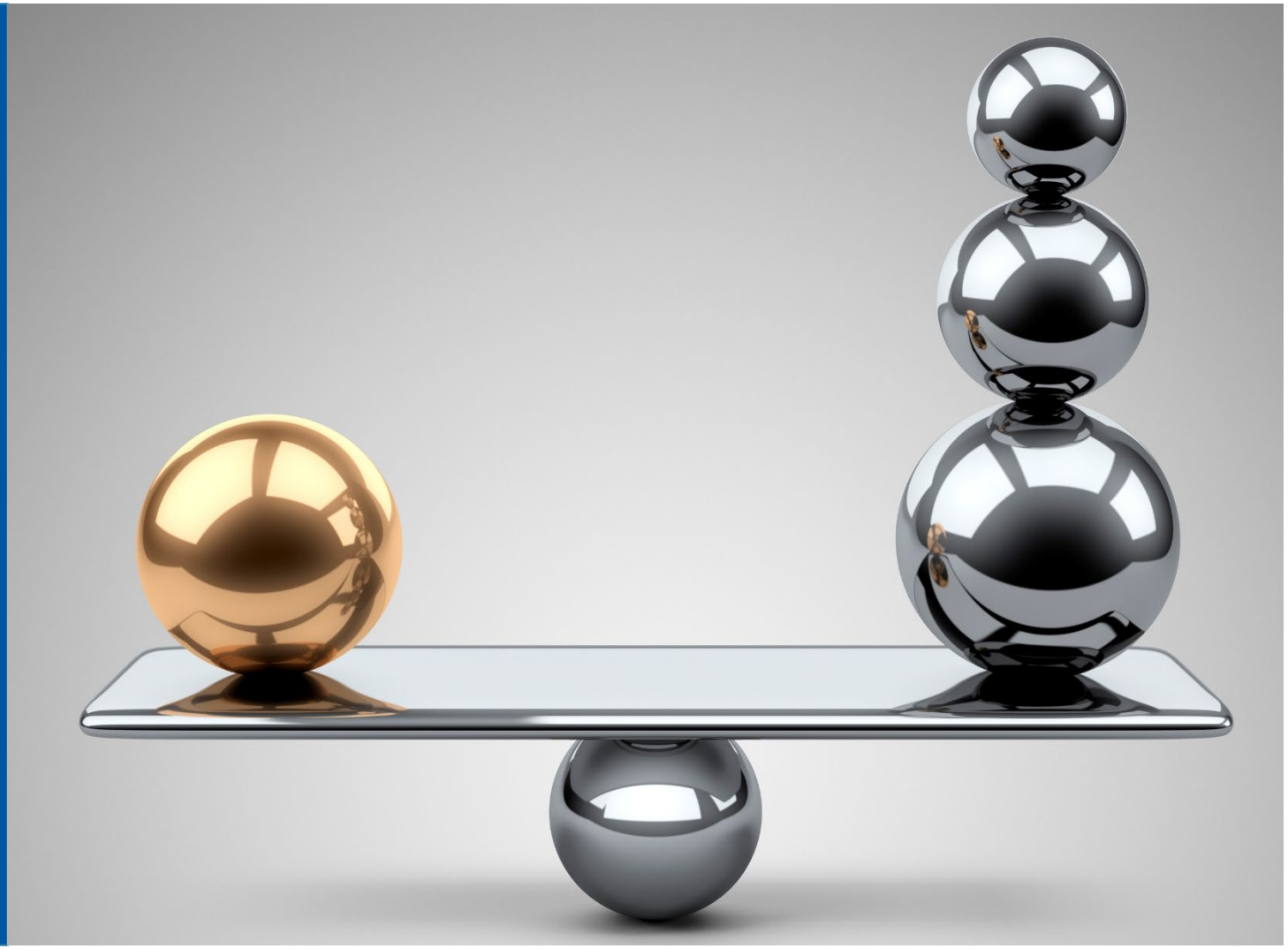
Are there market price proxies for the benefits?

Can we estimate the benefits?

- project databases...
- benefit catalogues...

05

Cost-Benefit viability indicators



Monetary flow of
costs, benefits and externalities

- **Costs schedules and expected benefits and externalities need to be yearly allocated**
    - Annual % distribution must respect cause-effect relationships
- **Service life of key assets must be compatible with the analysis horizon**
    - If service life is longer, insert residual value (benefit) at end of time series
    - If service life is shorter, rely on Repex
- **Analysis horizon must be compatible between the alternatives being analyzed**
    - Repeat the shorter ones until the deadline is reached
    - If this is not possible/sufficient, consider the equivalent annual value (EAV)
- **Evaluate the consideration of perpetuity (*yes* for projects with continuing characteristics)**
    - Perpetuity = annual value in the last year of monetary flow / social discount rate

Monetary flow of costs, benefits and externalities

Base Scenario

Project Scenario

Net Flow

Cenário Base (fazer o mínimo)											
Ano	0	1	2	3	4	5	6	7	8	9	10
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
CAPEX (R$)	0	113.202.743	149.070.691	124.925.438	94.831.355	72.523.241	14.522.145	33.768.361	56.076.475	79.959.279	67.011.825
OPEX (R$)	0	27.140.934	19.814.547	15.235.555	15.735.082	16.317.862	16.650.880	18.149.459	18.232.714	18.149.459	18.149.459
Valor do Tempo - Total (R$)	0	388.007.240	404.006.454	418.575.346	435.180.043	451.608.441	468.329.752	485.871.916	503.805.722	522.071.511	540.669.285
Segurança operacional - Total (R$)	0	178.569.996	180.102.806	180.620.446	185.414.805	186.232.575	186.750.215	188.800.665	189.318.305	190.136.075	191.886.395
Custos emissões GEE - Total (R$)	0	114.791.690	120.753.750	126.683.180	132.683.200	139.335.040	146.005.080	152.063.730	158.790.840	165.538.620	172.307.070
Custos de transporte - Total (R$)	0	1.750.239.169	1.841.906.008	1.933.348.541	2.025.507.985	2.128.055.419	2.230.844.503	2.323.769.572	2.427.230.594	2.530.964.637	2.634.971.699
Total Cenário (R$)		2.571.951.772	2.715.654.256	2.799.388.506	2.889.352.469	2.994.072.578	3.063.102.574	3.202.423.703	3.353.454.649	3.506.819.581	3.624.995.733

Cenário Alternativo (projeto de duplicação integral da rodovia)											
Ano	0	1	2	3	4	5	6	7	8	9	10
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
CAPEX (R$)	0	192.899.574	442.662.968	587.272.036	796.618.377	648.422.514	91.419.526	35.168.086	87.657.766	88.095.180	89.407.422
OPEX (R$)	0	41.960.218	49.203.350	53.615.834	56.612.992	59.027.370	60.442.694	60.525.949	60.609.203	60.692.458	60.692.458
Valor do Tempo - Total (R$)	0	388.007.240	399.585.768	407.124.841	411.372.112	414.549.619	417.089.489	432.713.539	448.686.592	464.954.688	481.517.826
Seg. Operacional - Total (R$)	0	178.569.996	174.062.703	165.459.898	154.334.519	139.334.163	123.977.831	125.218.926	125.495.397	125.942.523	127.012.963
Custos emissões GEE - Total (R$)	0	114.791.690	119.908.474	124.466.224	128.039.288	132.019.950	135.784.724	141.419.269	147.675.481	153.950.917	160.245.575
Custos de transporte - Total (R$)	0	1.750.239.169	1.832.498.046	1.908.632.823	1.973.677.755	2.046.279.087	2.116.429.913	2.204.542.080	2.302.610.182	2.400.945.844	2.499.549.065
Total Cenário (R$)		2.666.467.886	3.017.921.310	3.246.571.657	3.520.655.043	3.439.632.703	2.945.144.178	2.999.587.848	3.172.734.621	3.294.581.608	3.418.425.309

Cenário Comparativo (Cenário Base - Cenário Alternativo)											
Ano	0	1	2	3	4	5	6	7	8	9	10
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Δ CAPEX (R$)	0	-79.696.831	-293.592.277	-462.346.598	-701.787.022	-575.899.272	-76.897.381	-1.399.725	-31.581.291	-8.135.900	-22.395.597
Δ OPEX (R$)	0	-14.819.283	-29.388.803	-38.380.278	-40.877.910	-42.709.507	-43.791.814	-42.376.490	-42.376.490	-42.542.998	-42.542.998
Δ Valor do Tempo (R$)	0	0	4.420.686	11.450.505	23.807.931	37.058.822	51.240.262	53.158.377	55.119.130	57.116.823	59.151.459
Δ Segurança Operacional (R$)	0	0	6.040.102	15.160.547	31.080.285	46.898.411	62.772.384	63.581.739	63.822.908	64.193.552	64.873.431
Δ Custos das emissões (R$)	0	0	845.276	2.216.956	4.643.912	7.315.090	10.220.356	10.644.461	11.115.359	11.587.703	12.061.495
Δ Custos de transporte (R$)	0	0	9.407.962	24.715.718	51.830.230	81.776.331	114.414.590	119.227.491	124.620.412	130.018.793	135.422.634
Total (R$)	0	-94.516.114	-302.267.054	-447.183.151	-631.302.574	-445.560.126	117.958.396	202.835.855	180.720.027	212.237.973	206.570.424

It is the comparative net flow ("with" project - "without" project) that is brought to present value by the social discount rate (SDR)

Monetary flow of
costs, benefits and externalities

Social Discount Rate (SDR)

Weighs up the ***social opportunity cost***, based on:

- Domestic savings rate (household consumption)
- Return on private capital (profitability of firms)
- Cost of foreign debt (cost of public capital)

Examples:

- México: 10%
- Canada: 8%
- EUA: 2% a 3%
- Brasil: 8,5%

Net Flow

Cenário Comparativo (Cenário Base - Cenário Alternativo)											
Ano	0	1	2	3	4	5	6	7	8	9	10
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Δ CAPEX (R$)	0	-79.696.831	-293.592.277	-462.346.598	-701.787.022	-575.899.272	-76.897.381	-1.399.725	-31.581.291	-8.135.900	-22.395.597
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It is the comparative net flow ("with" project - "without" project) that is brought to present value by the social discount rate (SDR)

Calculating viability indicators

$$\Delta NPSV = \sum_{t=0}^{T} \frac{NetBenefits_t}{(1+SDR)^t}$$

Comparative Net Present Social Value (ΔNPSV)

Expressed in monetary units (MX$), it is the difference between the total benefits and costs brought to present value by the Social Discount Rate (SDR). It summarizes the net monetary balance, allowing it to be compared to any other investment options

$$0 = \sum_{t=0}^{T} \frac{NetBenefits_t}{(1+ERR)^t} + \frac{RV\ or\ PT}{(1+ERR)^T}$$

Economic Rate of Return (ERR)

Percentage (%), corresponds to the socio-economic return (discount rate that resets the ΔNPSV to zero). It is then compared to the Social Discount Rate (SDR): exceeding it fully covers the opportunity cost!

$$B/C = \frac{\sum_{t=0}^{T} \frac{Benefits_t}{(1+SDR)^t}}{\sum_{t=0}^{T} \frac{Costs_t}{(1+SDR)^t}}$$

Benefit-Cost Ratio (B/C)

Dimensionless (ratio between the present values of economic benefits and costs). It shows the result of the analysis in a very clear and simple way: benefits outweigh costs when B/C ratio is >1

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06

Dealing with risk and uncertainty

Decision theory and risk management

- **Behavioral biases**, which recognize that we are not ***that*** rational...
- **Imprecisions** arising from modeling, such as the inclusion of an externality, assumptions about demand growth, people affected, valuation parameters (WTP), cost estimates, valuations such as the social price of carbon, ...
- **Risks** can be of various kinds (technical, political, contractual, climatic...) and are exogenous to the decision-maker's control, but probabilities and severities can be established (with a certain degree of precision...), which allows for a quantitative approach (remembering that there will always be some remaining risk).
- **Uncertainty** occurs when the severity of an occurrence can be estimated, but probabilities cannot be established, which requires a qualitative and judgment-based analysis (think of a terrorist attack!)
- **Ignorance** is the most fragile situation, for which neither the potential severity nor the probabilities are known, which poses a significant challenge for decision-making, as there are few ways to assess the potential consequences

Decision theory and risk management

- **Behavioral biases**
- **Imprecisions**
- **Risks**

Proactively dealing with biases and inaccuracies

- Careful consideration of valuations with WTP
- Incorporating inconsistencies into decision-making (many simulations and result ranges rather than single figures)
- Probabilistic risk analysis (Monte Carlo method), calibrated for biases and inconsistencies

- **Uncertainty**

Judgments based on some guiding principles

- **maximin** (opting for the alternative with the 'best' of the worst-case scenarios)
- **breakeven** point (tests the reasonableness)
- **precautionary principle**, especially when unrealized benefits are small (be careful not to buy risk-risk!)

- **Ignorance**

Knowledge building and data acquisition...

Behavioral biases and their contours

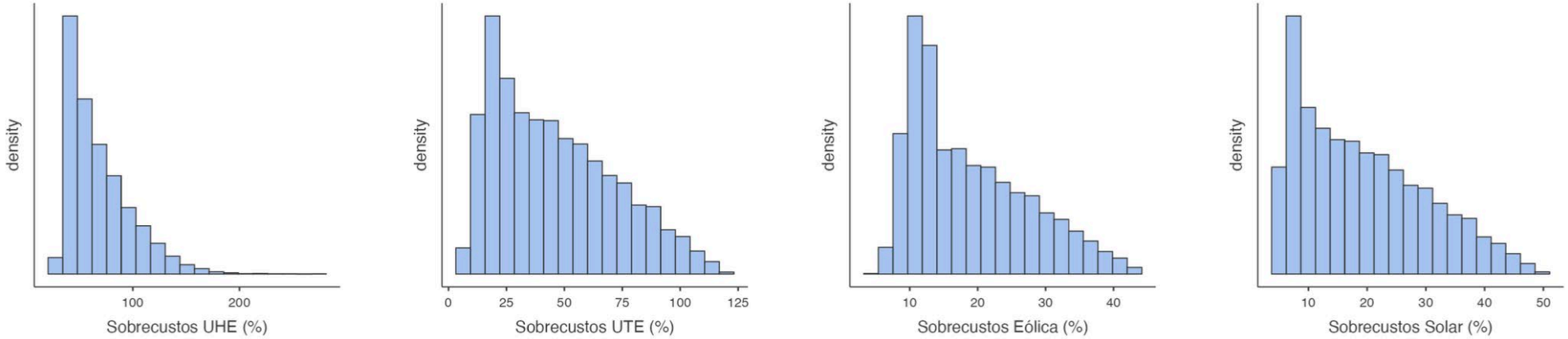
Behavioral biases were revealed by modern psychology and exposes the limitations of the neoclassical approach of the "utility-maximizing rational agent”

In CBA, we can account for the most significant issues using the same framework methodology

- **Adjusting risk perception and loss aversion**
    - Incorporate loss aversion into the utility function, which prescribes greater sensitivity to losses and decreasing sensitivity to gains
- **Incorporate expected deviations into expected utility**
    - Use probabilistic risk analysis to actively test whether there is a false "anchoring" in relation to a reference point that is unlikely or disconnected from evidence (one of the main reasons behind cost overruns and delays)
- **Simulate time inconsistency**
    - Use of a non-exponential social discount rate to introduce risk into the time value (capital impatience)

Probabilistic analysis (Monte Carlo method)

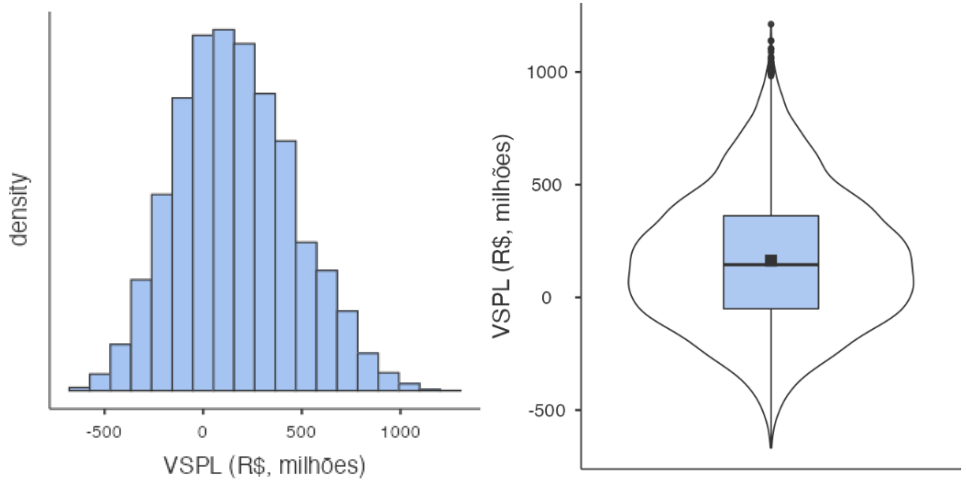
- A **probability distribution** is assigned to each **critical variable**, defined as a range of values around the best available estimate
- This distribution can be derived from different sources (experimental data, distributions found in the literature, consultation with experts, etc.)
- Example: variability in the incidence of cost overruns (affecting Capex) for energy projects in Brazil, following the **triangular distribution** and **minimum**, **maximum** and **mode** values: 1.2 - 120 - 14.3 for UTE; 0.4 - 44.4 - 8.6 for wind; and 2 - 50 - 4.8 for solar



Callegari C.L., Szklo A, Schaeffer R: Cost overruns and delays in energy megaprojects: how big is big enough? Energy Policy 2018, 114:211-220.

Probabilistic analysis (Monte Carlo method)

- An estimate of 9,999 results is made based on the random drawing of the variables, considering their probability distributions and values
- The result of a Monte Carlo analysis is in itself a **probability distribution of possible results!**



Aggregate results of 9,999 simulations	ΔNPSV Comparative Net Present Social Value (R$, million)
Final CBA indicator (*baseline*)	252,49
Average	163,23
Standard Deviation	296,37
Minimum	-668,38
1st Quartile	-50,73
Median	145,11
3rd Quartile	361,53
Maximum	1.212,28

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Not all CBAs will be the same...

Assuming that some key benefits are difficult to quantify, or that there is a considerable degree of uncertainty, we can carry a *Conditional CBA* or *Break-even CBA*

- If social gains will be substantial, we can reason, for example: "if each consumer gets only MX$0.20 of benefit, the project already outweighs its costs"
- The reasonableness of the decision is tested against its costs (and at least the benefits are qualitatively expressed, which helps in the decision-making process)
- Quantifying social costs and some benefits is already part of a much more informative and systematic process than quantifying nothing...
- Assumptions / suppositions / extrapolations should be stated and substantiated based on analysis of similar past occurrences (in other jurisdictions / countries / sectors)
- Monitoring indicators makes it possible to revise assumptions in order to base future interventions... in other words, to deal proactively with a lack of knowledge

How to deal with incomplete information

- **State it! Make explicit all-important premises / assumptions / extrapolations**
  - Allows for subsidies, sensitivity analysis and ex-post analysis
- **Obtain informational subsidies (informal and formal)**
  - Dispersed among stakeholders (airline companies, regulatory agencies, users, academia...)
- **Ex-post analysis**
  - Allows for improvements to project design practices (***your*** project isn't the last project!)
- **Evaluation and experimentation**
  - Use of randomized trials provides **real information** (it may be very difficult, but it is "gold standard")
- **Adopt, measure and react**
  - In the case of modular changes or changes that can be reversed, you can measure the results in "real time" to change course if necessary (requires precise indicators and pre-established triggers)

When dealing with climate change adaptation measures...

Should the project **remain viable (benefit>cost)**, even in the absence of climatic impacts

- ***no-regret* alternative**

Should the project remain viable with **little additional expenditure**

- ***low-regret* alternative**

Should the project **be only viable** in atypical situations (extreme risks, for instance)

- declared unfeasible... and **back to the drawing board**

Should the project **be only unfeasible** in atypical situations (extreme risks, for instance)

- feasibility is declared... and **we need to address residual risk** (e.g. insurance, phased implementation or even design improvements that can be made at a later date)

Group Exercise

Stylized case of economic appraisal

Groups of 4-6

Let’s mix skills and perspectives!

The task is to develop a ***conceptual*** case study for air navigation projects

Groups will develop it over the course, so stick to the task at hand right now ->

4th task

What are the risks and uncertainties?

Continuing the group’s stylized case:

Discuss the risks and uncertainties involved

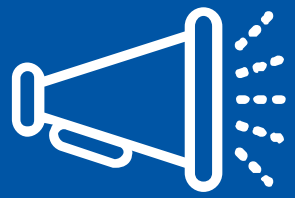
How to deal with the risks and uncertainties within the CBA framework?

Class-reference setting:

what can be learned from past experiences?

Group Exercise

Stylized case of economic appraisal



Time to present and discuss our findings!

Thank You!

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