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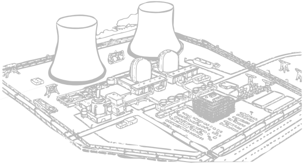

Benefit-cost analysis for land-use planning: a case study

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Would this project provide a net benefit to society?

Warmup. Before reading this material, we suggest you consult the associated slides on Benefit-cost analysis for risk-related decision-making.
Available from `risk-engineering.org` & `slideshare.net`

Context

- Land use planning raises numerous complex questions:
  - which criteria should society use for ALARP decisions?
  - which balance between different methods of reducing risk from a facility should be implemented?
- Benefit-cost analysis: a **decision-support tool** which can help discussion with stakeholders concerning these questions:
  - **structured framework** for presenting all the components of a decision and their different weightings
  - increasing the **transparency** of the decision-making process
  - provides a **historical record** of the elements considered in a decision
    - and the level of uncertainty existing at the time the decision was made

Case study

- Study undertaken by the author and the Toulouse School of Economics, on behalf of the industrial operator (France, 2007)
- Compared three scenarios for a maritime LPG importation and refilling site:
  1. safety barriers proposed by plant operator (removal of one LPG sphere, removal of railway wagons on site, reduction of quantity of gas stored on site)
  2. mounding LPG spheres to protect from impinging ame (measure imposed by competent authorities)
  3. closure of the facility, with current clients being supplied by truck from another facility
- Relatively dense urbanization around the site:
  - > 7 000 people within a 900 m radius
  - potential domino effects towards neighboring facilities

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Steps comprising a BCA

1. Specify the perimeter of the analysis
   - list of economic agents for whom we will estimate the consequences of the scenarios
2. List the consequences of the scenarios and choose ways of measuring them
3. Provide a quantitative prediction of the consequences for each scenario, over the project lifetime
4. Monetize the consequences
   - convert them into a monetary unit to allow comparison
5. Discount future benefits and costs, in order to obtain the net present value of each scenario
6. Analyze the robustness of the results obtained by undertaking an uncertainty analysis for the main uncertain input parameters
7. Recommend a decision

Consequence estimation

- ▷ 420 people (in addition to 22 workers on site) working or living within a radius of 360 m
- ▷ 6 700 people living between 360 and 900 m
- ▷ 24 500 people living between 900 and 1 600 m

Hazards considered

- Hazardous phenomena:
  - unconfined vapour cloud explosion (UVCE), due to a leak of flammable gas to the atmosphere which explodes some time after the time of release
  - jet fire, a large flame due to a leak of gas to the atmosphere which ignites close to release point
  - BLEVE
- Accidental scenarios considered:
  - BLEVE of LPG transport trucks, railway wagons, or large LPG storage spheres (envelope scenario)
  - pipe ruptures, for pipes of small and large diameter
  - the rupture of loading mechanisms for railway wagons or trucks
- Probabilities and consequences taken from the safety case

Consequences excluded from study perimeter

- Impact on firm's image in case of an accident
  - very difficult to estimate
  - would depend strongly on how the accident was reported in the media
- Strategic value for France of an LPG importation location not monetized
- Impact on productivity in each scenario is assumed to be negligible

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Study assumptions: benefits

- Averted fatalities and injuries:
  - 2.5 M€ per statistical fatality (upper value recommended by EU)
  - 300 k€ for severe industrial injury (UK HSE)
  - 225 k€ for severe road accident, 33 k€ minor road accident (French ministry)
- Avoided material damages:
  - value of industrial facility is estimated at 25 M€
  - nearby industrial installations: 67.5 M€
  - LPG tankers and cargo boats potentially at port: 60 M€
  - lost production of firms in nearby industrial zone: 5 M€
  - house in potentially affected area: average 150 k€, apartments 120 k€
  - replacing window frames and windows: 5.5 k€ per household
  - average household has 1.5 vehicles, each worth 15 k€

Study assumptions (scenario 3)

- ▷ Site closure ⟶ estimated increase in 475 000 km/year in road traffic
- ▷ 400 000 km of trucks with small LPG bottles
- ▷ 75 000 km for LPG tankers
- ▷ Annual consequences of extra traffic [accident statistics concerning hazardous materials transport]:
  - $366 \cdot 10^{-5}$ statistical deaths
  - $2\,928 \cdot 10^{-5}$ severe injuries
  - $5\,124 \cdot 10^{-5}$ light injuries
- ▷ Environmental impact (external cost of CO_2 emissions) ≈ 0.6€/km
- ▷ Dismantling the facility is assumed to have a zero net cost
  - sale of scrap metal from the installations would compensate for labour costs

Study assumptions: costs

- Investment for scenario 1: 1.5 M€
- Investment for scenario 2: 10 M€
- Extra operating costs for scenario 3: 1.1 M€ per year
  - higher LPG purchasing costs at other importation sites on the French west coast
  - additional road transport
- Investment horizon: 15 years
- Social discount rate of 4%
- Cost of lost employment on the site (both direct and indirect) over 4 years (scenario 3): 1.2 M€

Summary of benefits and costs

	Scenario 1	Scenario 2	Scenario 3
Benefits			
Averted fatalities	6 275	6 400	-1 169
Averted injuries	2 745	2 817	-5 060
Material damage avoided			
On site	950	675	4 000
Off site	1 045	1 016	1 087
Sum of benefits	*11 015*	*10 908*	*-1 142*
Direct costs			
Investment	129 723	864 818	0
Distribution overheads	0	0	1 100 000
Other direct costs	0	0	43 241
Indirect costs			
Environmental costs	0	0	2 850
Lost indirect employment	0	0	103 778
Sum of costs	*129 723*	*864 818*	*1 249 869*
Net annual benefit	**-118 708**	**-853 910**	**-1 251 011**

Note all scenarios have a negative net benefit (BCA recommends against these decisions)

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Interpretation

- Closure of site would lead to an *increase* in the level of risk to which inhabitants of the region are exposed
- Scenarios 1 and 2 would result in levels of technological risk which are within the same confidence interval
  - cost of the second scenario is 7 times greater than the first
- Alternative presentation: net cost to society of each statistical death averted by implementing the safety measure is 50 M€ for scenario 1 and 332 M€ for scenario 2
  - 1.5 M€ for public investment in road safety projects in France
  - 2.5 M€ for regulatory impact assessment of EU legislation on air quality
- Suggests that scenarios 1 and 2 are *inefficient*: larger number of fatalities could be avoided if spending were allocated to other classes of risks

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Uncertainty analysis

Parameter	Best estimate (μ)	Std dev (σ)
Killed per billion road km	7.0	0.3
Value of neighboring site A	50 M€	5 M€
Value of the studied site	25 M€	2 M€
Multiplier for accident consequences	1.0	5
Value of a statistical life (VSL)	2.5 M€	1 M€
Cost of an injury (industrial accident)	300 k€	30 k€
Cost of a severe injury (road accident)	225 k€	25 k€
Cost of a light injury (road accident)	33 k€	3 k€
Interest rate	4%	1%
Temporal horizon for investment	15 years	3 years
Costs in scenario 1	1.5 M€	0.15 M€
Costs in scenario 2	10 M€	1 M€
Extra costs for alternative LPG sourcing	1.1 M€	110 k€
Extra km in scenario 3	450 k€	45 k€

The main uncertain input variables, represented using Gaussian probability distributions

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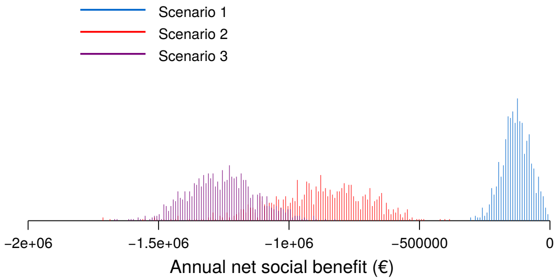
Robustness of the conclusions



The figure shows the distribution of the annual net social benefit of each scenario, compared with the status quo. The distribution is obtained using a Monte Carlo analysis which randomly samples the main uncertain quantities in the analysis (see previous slide) from their probability distributions.

This uncertainty analysis shows that the conclusions are robust: with most possible combinations of uncertain input variables, the ordering of scenarios (in terms of social net benefit) remains the same.

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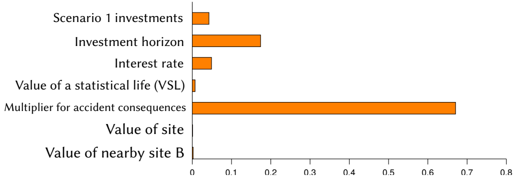
Sensitivity analysis



A global sensitivity analysis using the FAST method shows the relative contribution of the uncertainty of the main input parameters to the overall output uncertainty (their *sensitivity index*).

For scenario 1 (figure on left), the main contribution to uncertainty in the net social benefit comes from the uncertainty in the probability of the various accident scenarios.

For scenario 3 (not shown), the main contribution to uncertainty is the additional cost of sourcing LPG from another location.

What results from this study?

- ▷ Results were presented to the competent authorities by the site operator
- ▷ Authorities required implementation of scenario 2
  - risk-informed and cost-informed argument was rejected
- ▷ Argument not judged sufficiently convincing to override a *Best Available Technology* approach
  - national doctrine requiring flame-proof mounds
- ▷ Argument based on concepts such as statistical value of life was judged difficult to defend politically
- ▷ National doctrine concerning the management of technological risk is based on uniform thresholds defining acceptable exposure to risk
  - little latitude for the integration of cost considerations
  - low impact of local preferences

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