11.4 The ALARA programme : The decision aiding techniques rationale and exercises

The aim of decision aiding methods: to selecting protection actions

The objective:

- - to select the most efficient group of actions for reducing doses at a reasonable cost

The methods:

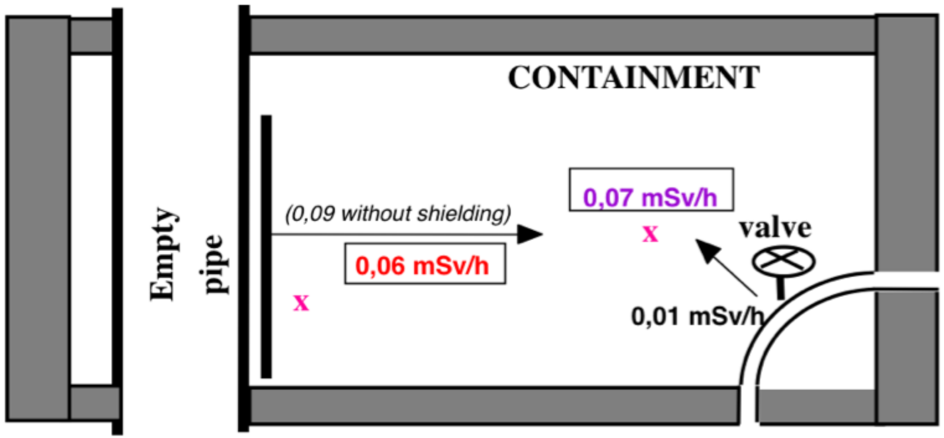
- - differential cost-benefit analysis (cost efficiency analysis),
- - cost-benefit analysis,
- - multicriteria analysis…

One of the tools:

- - the monetary value of the man-sievert

Reminder from the theoretical case study 1
Quantification of criteria: cost and efficiency

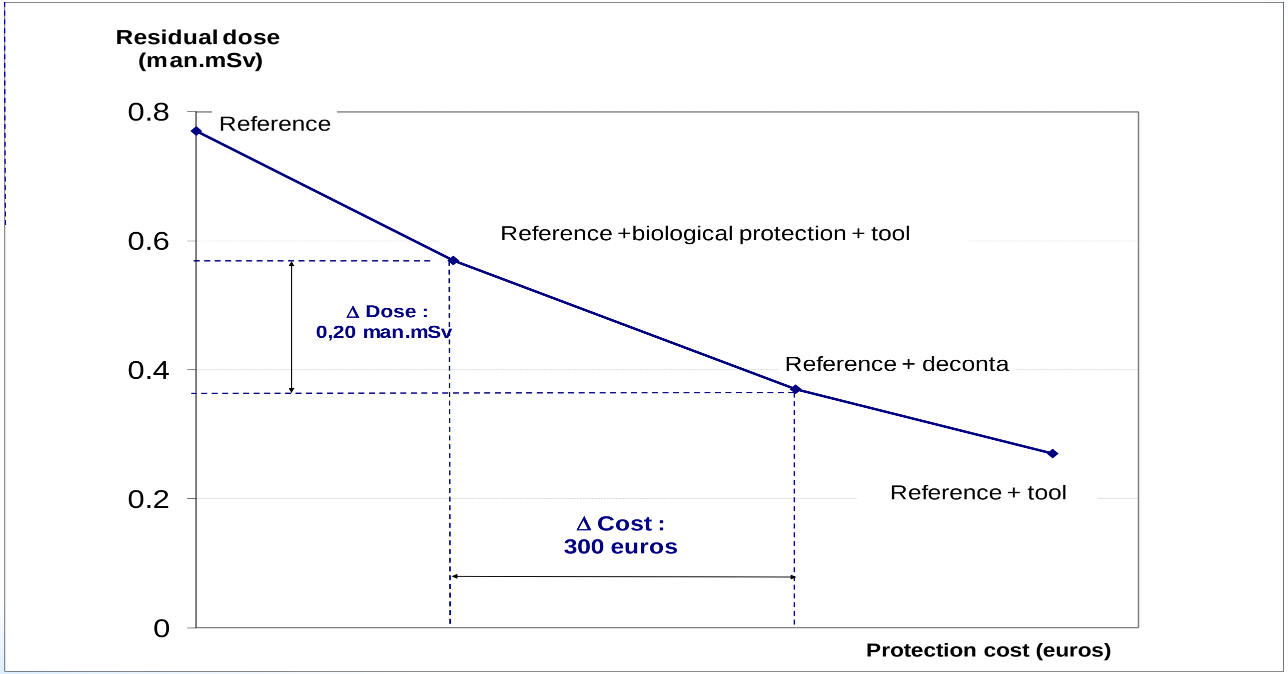
To install the biological shielding



Reminder from the theoretical case study 2 Differential cost-benefit analysis

Action	Cost	Δ Cost	Collective dose	Δ Dose	Δ Cost/Δ Dose
Initial situation			2.5 man.mSv		
Reference (water + light + distancing)	Almost nil	-	1.11 man.Sv	1.39 man.mSv	-
Reference + biological shielding	Almost nil	-	0.77 man.mSv	0.34 man.mSv	-
Reference + tools + biological shielding	250 €	250 €	0.57 man.mSv	0.20 man.mSv	1250 €/man.mSv
Reference + decontamination	550 €	300 €	0.37 man.mSv	0.20 man.mSv	1500 €/man.mSv
Reference + tools + decontamination	800 €	250 €	0.27 man.mSv	0.10 man.mSv	2500 €/man.mSv

Reminder from the theoretical case study 3
Analysis: where to stop? What is reasonable?



Reminder from the theoretical case study 4
Analysis: Existence of a reference value

Reference monetary value of the man-sievert: 1800 €/man.mSv

The optimal action is the acceptable action providing with the largest collective dose decrease. Here it is reference+ decontamination.

Where does the 1800€/man.mSv come from?

Existence of a reference value

Who decides such a reference value ?

- Generally the management

Where does it exist?

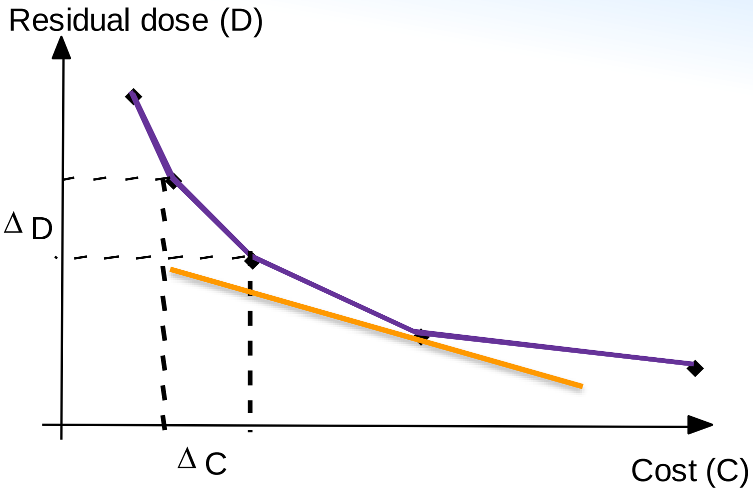
- in most facilities in the nuclear field

Is there a method to assess it ?

- ICRP proposed a method to assess it;

Let's present the ICRP methodology

Selection of protection actions
Differential cost benefit analysis



- ΔC/ΔD : implicit cost of an avoided dose unit
- The more we try to reducing the dose the more that costs grows
- α : reference monetary value of a dose unit
  => "what is agreed to be paid in order to avoid one dose unit "
- **Optimum** : ΔC/ΔD ≤ α α corresponds to the slope of the red line

So what is alpha, the man.Sievert monetary value? The ICRP method called human capital method (1)

It is a predefined value, corresponding to what a regulatory body or utility institution consider as a maximum to pay for avoiding one man Sievert

It can be assessed in different ways : here after the ICRP way

The man-value of the man.sievert is equal to: the probability to have a radio-induced health effect multiplied by the monetary value attributed to that health-effect

The health effect may be expressed as a number of years of life lost. Their monetary value is relying on the monetary value of one "year of life lost" (i.e.. monetary value of the human life)

The ICRP method called human capital method (2)

- Human capital approach: the monetary value of one year of life is assessed in dividing the annual wealth production of a country by its number of inhabitants

Gross national product per inhabitant (France 2002)	21 K€
Number of years of life lost per radioinduced health effect	16 years
Monetary value of a radioinduced health effect	**16 x 21 = 0,34 M€**
Probability of health effect occurence (value)	5,6 x 10^{-2}/Sv
Monetary value of radioinduced health effects corresponding to 1 man-Sievert	**0,34 x 5,6 x 10^{-2} = 19 K€ / man.Sv**

The ICRP method called human capital method (3) the limits

19 000 € per man.Sievert implies 19 € per man.mSv

In the previous theoretical case no option but those with no cost should have been implemented "reasonably" and we have seen that the value used by the utility was about 100 times higher (1800 € per man.mSv)

Therefore the human capital approach can only be considered as a minimum requirement

Other approaches have been developed with results more coherent with practices

The man.Sievert monetary value taking care of the risk aversion (1)

Three objectives:

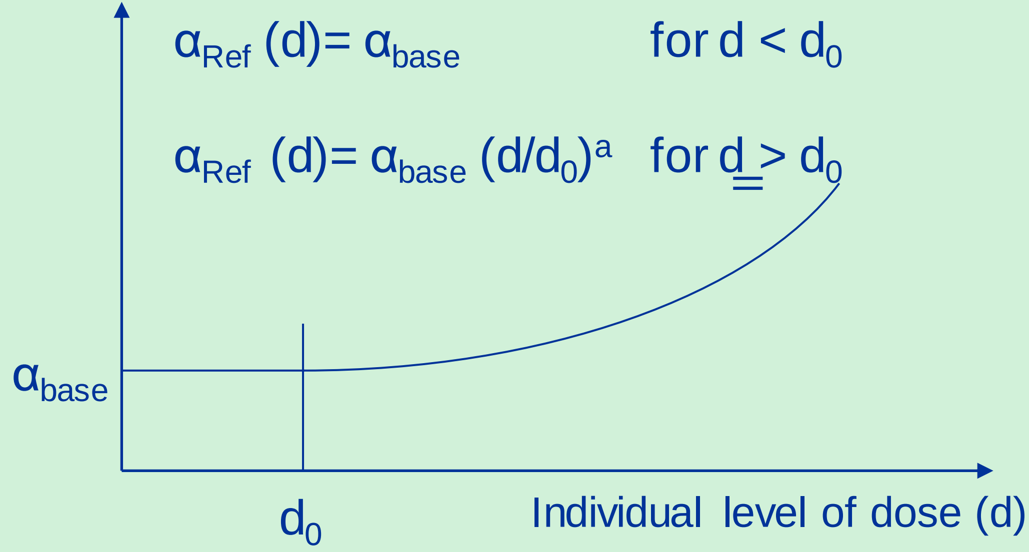
- To reduce collective exposure
- To reduce individual exposures dispersion
- To reduce in priority highest individual exposures

A model for the man.Sievert monetary value taking care of the risk aversion (2)

Monetary value of the unit of collective dose

$\alpha_{Ref}(d) = \alpha_{base}$ for $d < d_0$

$\alpha_{Ref}(d) = \alpha_{base}\,(d/d_0)^a$ for $d \geq d_0$



The model parameters

a_{Base} Value (minimal monetary value of the man.Sv)

- Assessed with the Human Capital Approach

”d_0" Value (individual dose above which the man Sievert monetary value starts to increase)

- In case of occupational exposure, it is the public dose limit 1mSv.

“d” is the individual level of exposure

“a" Value (risk aversion coefficient)

- Values published: between 1.2 et 1.8 (recently upgraded up to 2)

Using that model EDF, the French nuclear operator has set up a system in 2003

Annual individual dose level (mSv/year)	Monetary value of the man.Sievert (€/man.mSv)
	a = 1.5 and alpha base = 19
0 - 10	650
10 - 16	1300
16 - 20	1800

Exercise

A group of scaffolders has an annual average individual dose of 8 mSv and an expected collective dose for an operation of 20 man.mSv.

In order to reduce their collective dose there are 2 options that may be combined

Option	Collective Dose (man.mSv)	Cost (€)
A	18	500
B	16	4000
A+B	14	4500

Exercise

Making use of the EDF system and of the differential cost benefit analysis (cost efficiency analysis) answer to the following questions

- What is the reference?
- What is the optimal situation?
- Does it change anything if the scaffolders have an average annual dose of 12mSv?
- What is the interest of the sensitivity analysis?

Exercise

reference	20	0	
A	18	500	
B	16	4000	
A+B	14	4500	
	delta dose	delta cost	delta dose /delta cost
A	2	500	250
B	2	3500	1750
A+B	2	500	250
	optimal A if average annual dose is 8 mSv		
	optimal A+B if annual dose is 12 mSV		

When data are available on each individual annual dose the cost benefit analysis

It is possible to directly use the model and to calculate the so called cost of the detriment by multiplying the annual dose of each worker by its own man.Sievert reference value.

This will be done first for the reference situation and then for each new situation when implementing one or several options.

For each situation, we will then have the cost of the protection actions and the cost of the detriment: adding the will provide the total cost.

The optimal situation will be the one with the lowest total cost.

That method is called the “cost benefit analysis” and is illustrated during the lecture on Optimization at the design stage of an installation.

Who decide to set up a system?

- The utilities (most often in the nuclear sector)
- The experts bodies (recommendations in UK for example)
- The regulatory bodies (very rarely)

Some regulatory bodies values (Safety report 21)

Country (year)	Monetary value of a man-sievert in the national currency	in US $ Monetary value of a mansievert
Canada (1997)	Can $ 100 000, established on the basis of international references	75 000
Czech Republic(1997)	CZK 500 000–5 000 000, depending on the level of the individual doses and the exposure situation	17 000–170 000
Finland (1991)	US $100 000, value common to all the Nordic countries	100 000
United Kingdom(1993)	£10 000–100 000, depending on the exposure situation (not plant specific) and the level of the individual doses	17 000–170 000
Netherlands (1995)	NLG 1 000 000	500 000
Romania (2000)	US $220 000	220 000
Sweden (SSI) (1992)	SEK 400 000–2 000 000	55 000–270 000
USA (NRC) (1995)	US $200 000	200 000

Note: 1 US $ = Can $1.33, CZK 30, £0.6, NLG 2, SEK 7.5, (as at 1998).
SSI: Swedish Radiation Protection Authority. **NRC:** Nuclear Regulatory Commission.

Role of authorities values

In most countries, they are minimum basic values (UK, Scandinavia, USA, ...); mainly a few tens of thousands of US dollars per man.Sievert (a few tens of US dollars per man.mSv)

They are only recommendations

"Risk aversion is one of a number of factors... Other factors include the proximity of individual doses to regulatory or local investigation levels, or the general corporate pressures on radiological safety. As such, it is entirely reasonable for organisations to adopt monetary values of unit collective dose for internal use that are larger than those recommended by the Board“.

(Doc. NRPB Vol. 4, n° 2, 1993)

Some Utilities values (Safety report 21)

IAEA

Country	Utility	Year of adoption	Monetary value of a man-sievert in the national currency	Monetary value of a man-sievert in US $
Canada	Gentilly	—	Can $1 000 000	750 000
Romania	Cernavoda	2000	US $220 000	220 000
Slovenia	Krsˇko	1996	US $700 000	700 000
South Africa	Koeberg	1993	US $1 000 000	1 000 000
Spain	Asco Vandellos	1994 1982	US $2 000 000 ESP 100 000 000	2 000 000 700 000
Sweden	Value common to all the utilities	1992	SEK 4 000 000	550 000
USA	Value per utility for 90% of the reactors	1990–1991 in general, 1993–1997 for the highest values	Min. value : US $500 000 max. value: US $2 810 000 medium value: US $1 200 000 average value: US $1 000 000	Min. value:, 500 000, max. value: 2 810 000, median value: 1 200 000 average value: 1 000 000

Note: 1 US $ = Can $1.33, ESP 150, SEK 7.5 (as at 1998).

Some Utilities values

Most utility values (when single values) are exceeding five hundred of thousands and even more than one or two millions of US dollars per man.Sievert (>1000 to 2000 US dollars per man.mSv)

Other data exist for utilities using sets of values: the maximum values then always exceed 1 million US dollars up to 2.5 millions

More recent data on the alpha value are available and provided in "Radioprotection", Volume 55, Number 3, July-September 2020, Edited by the SFRP (French Society for Radiation Protection)

Alpha values

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As a conclusion on the man.Sievert monetary value

It is a tool for

- efficiency
- equity
- transparency
- coherence

within radiation protection decisions

It has a (several) value (s) corresponding to

- The economic and social resources
- The objectives of the utility
- The exposure conditions

As a conclusion is it often used?

Not so often

- Generally only for very important decision needing to follow a very formalised procedure with important stakes in terms of costs; and this mainly in the nuclear sector
- Even in that case very often, other criteria have to be taken into account
- This lead then to use some multicriteria approaches as illustrated in several case studies (in the medical area ,…)

Other possible decision criteria

- Length of the operation
- Impact on the availability of the installation or workplace
- Impact on the effluent and waste levels
- Impact on technical processes
- Impact on the safety of the installation
- Impact on the other occupational risks
- Impact on accessibility
- Impact on other following operations
- Impact on patient doses
- Impact on risks for the public
- Impact on equity
- Impact on source security
- …

Multi criteria methodology

As in the cost efficiency and cost benefit analysis the steps of the optimization procedure must be followed, which means that after the brainstorming for defining all possible options (or strategies) it is mandatory to **quantify each criterion for each option or combination of options**

When the criterion is qualitative, it will be given a mark between 0 and 1 (or 0 and 10 or 0 and 100) with the best situation receiving the highest mark (the size of scale will the decision of the firm). The mark will be given making use of the "engineer – or medical doctor, or researcher, or RPO" know how.

ex: the option allow to reduce drastically the wastes it will ranked "1" on the impact of waste criterion

Multi criteria methodology (1)

When all criteria have been given a mark for an option (or strategy), one can add all marks for a given option or set of options

The best option may be then the one with the highest total

Option	Criterion 1	Criterion 2	Criterion 3	Global mark
A	0,6	0,3	0,1	1
B	0,5	0,7	1	2,2
C	0,3	0,1	0,6	1
…				

Multi criteria methodology (2)

One can also envisage to weight differently the criteria before for the addition

For example one can consider that *the impact on waste is 3 times less important than the impact on the safety of the installation*; in that case the mark for the safety of the installation my be multiplied by 3 before to make the addition.

Option	Criterion 1 Weight =1	Criterion 2 Weight =3	Criterion 3 Weight =1	Global mark
A	0,6	0,3	0,1	1,6
B	0,5	0,7	0,1	2,7
C	0,3	0,1	0,6	1,2
…				

Multi criteria methodology (3)

As presented in some case studies it is also possible not to give a mark but just to put +, ++, +++ or -, --, --- for each criterion and to provide the decision maker just with a synthesis table

Option	Criterion 1	Criterion 2	Criterion 3	Criterion 4
A	++	-	--	---
B	+	++	+++	+
C	-	--	+	+
…				

Decision aiding tools' role

All the presented methods remain decision aiding tools **ONLY**

The most important is that they oblige to take time to think about all factors, all criteria; to make efforts to quantify all of them even when they are qualitative

It is of course much better in the decision making process than just arguments without any information about the actual importance of each argument.

But finally the decision remain the role of the decision maker as stated in the formalized procedure depending on the stakes.

Having described structures, procedures and tools one can keep in mind that:

Degree of implementation of the ALARA approach	Average percentage of dose due to mishaps (min. - max.)
Lack of a structured ALARA approach	70 % *(50-80)*
No ALARA planning, but ALARA commitment during the job	40 % *(30-50)*
ALARA planning and follow-up Unfamiliar technology used in the operation or first operation of its kind	30 % *(15-40)*
ALARA planning and follow-up Use of feed back experience from earlier operations	10 % *(0-30)*

The better Optimization is implemented, the lower "unjustified doses" are provided to the workers