EO-1

CONCEPT AND APPLICATION OF OPTIMIZATION FOR RADIOLOGICAL PROTECTION

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BACKGROUND OF OPTIMIZATION (1)

1.BASIC FRAMEWORK OF RADIATION PROTECTION

- **To prevent the occurrence of deterministic effects.**
- **To ensure that all reasonable steps are taken to reduce the introduction of stochastic effects.**

2.PRUDENT ASSUMPTION OF LINEAR NON-THRESHOLD

- **Some additional risk of cancer from any increment of dose above natural background.**

BACKGROUND OF OPTIMIZATION (2)

3.BALANCE BETWEEN RESOURCES AND DOSE REDUCTION

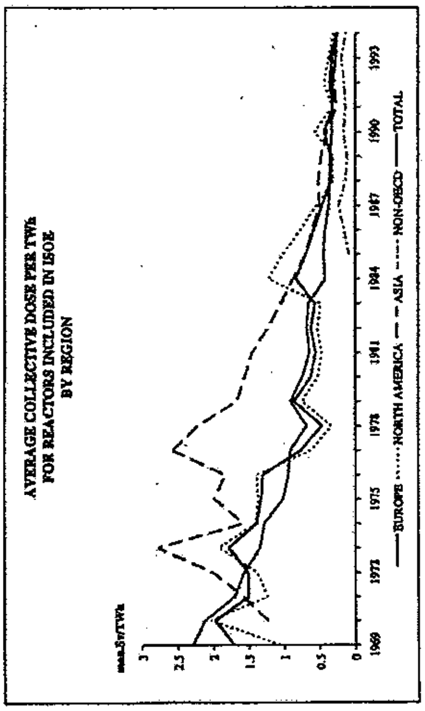
- ♦**What scale of resources should be provided for reducing the radiation risks to individuals and society.**
- ♦**How the resources can best be allocated.**

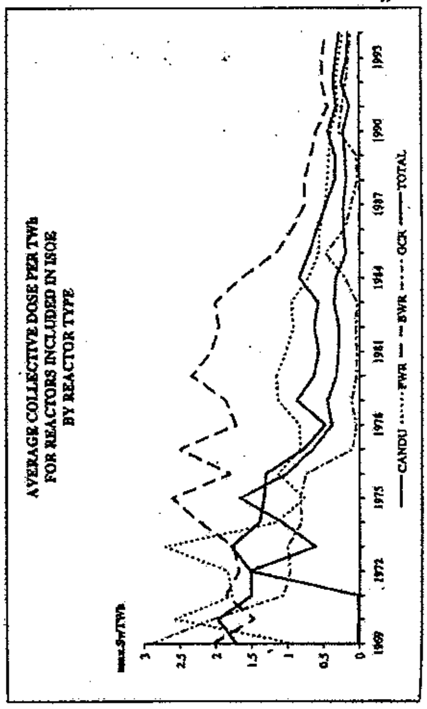
4.OPTIMIZATION

- ♦**The concept of keeping "all doses as low as can reasonably be achieved, economic and social factors being taken into account."**

The evolution of the recommended dose limits of the total body to ionizing radiations.

Year	Authority	Original units		mSv/year		References
		Occupational	Public	Occupational	Public	
1902	Rollins	10 r/day		36500		Morgan , 1967
1925	Mutscheller	0.2 r/day		500		Mutscheller , 1925
1931	(NCRP)	0.2 r/day		500		NBS , 1931
1934	(ICRP)	0.2 r/day		500		IXRPC , 1934
1936	(NCRP)	0.1 r/day		250		NBS , 1936
1949	NCRP	0.3 rem/week	0.03 rem/week	150	15	NBS , 1949
1950	ICRP	0.3 rem/week		150		ICRP , 1951
1952	NCRP		0.03 rem/week		15	NBS , 1953
1956	ICRP	0.1 rem/week		50		ICRP , 1956
1957	NCRP	0.1 rem/week		50		NBS , 1957
1958	NCRP		0.01 rem/week		5	NBS , 1958
1959	ICRP		0.01 rem/week		5	ICRP , 1960
1977	ICRP	50 mSv/year		50		ICRP , 1978
1985	ICRP		1 mSv/year		1	ICRP , 1985
1990	ICRP	20 mSv/year		20		ICRP , 1991





Potential Impact of Radioactive Source Reduction Techniques on Nuclear Power Plant Collective Occupational Exposures.

Technique	Potential Impact on Collective Dose[1]			Remarks
	Short term[2]	Intermediate term[2]	Long term[2]	
Cobalt reduction	low	medium	high	Largest impact on new plants
Preconditioning	low	medium	medium	For new plants and replaced components
Water chemistry	medium	medium	medium	Cost-effective technique
Component decontamination	medium	low	low	More effective for older plants
Full system decontamination	–	medium	low	Critical-path savings
Low waste decontamination process	–	medium	low	Low waste-handling cost
Advanced reactor designs	–	medium	high	Very large source reductions possible

1.Relative to the annual collective dose at the beginning of the appropriate period.

2.Short (<7 years), intermediate term (7–20 years), long term (>20years)

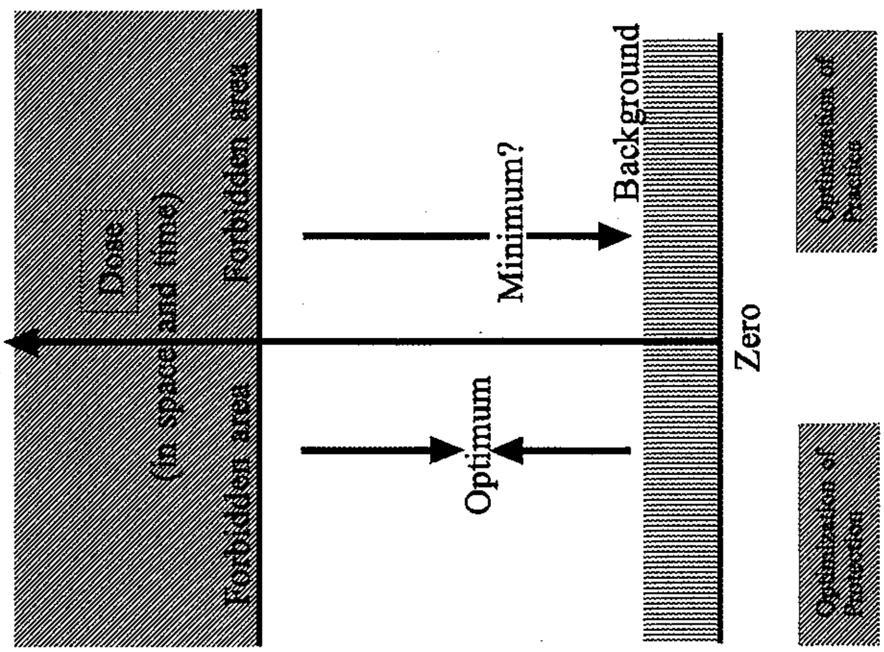
Potential Impact of Exposure Time Reduction Techniques on Nuclear Power

Plant Collective Occupational Exposures.

Technique	Potential Impact on Collective Dose[1]			Remarks
	Short term[2]	Intermediate term[2]	Long term[2]	
Improved materials	low	medium	medium	Significant for component replacement and new plants
Control of IGSCC of BWR piping	medium	medium	low	Important for present BWRs
Control of PWR sterm generator tube corrosion	medium	medium	low	Important for present PWRs
Remote tools	low	low	medium	Significant for new and standerdized plants
Robotics	low	medium	medium	Need rugged, reasonably priced devices
Operational and maintenance techniques	low	medium	medium	Very cost-effective for dose reduction
Advanced reactor designs	–	medium	high	Offer new possibilities for remote tools, robotics, etc.

1.Relative to the annual collective dose at the beginning of the appropriate period.

2.Short (<7 years), intermediate term (7-20 years), long term (>20years)



Schematic Representation of the Optimization of Radiation Protection and the Optimization of Practice.

ICRP 1955

TO THE LOWEST POSSIBLE LEVEL

Whilst the values proposed for maximum permissible doses are such as to involve a risk which is small compared to the other hazards of life, nevertheless, in view of the incomplete evidence on which the values are based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposure to all type of ionizing radiation to the lowest possible level.

ICRP Publication 1 (1959)

AS LOW AS PRACTICABLE (ALAP)

It is emphasized that the maximum permissible doses recommended in this section are maximum value: the Commission recomends that all doses be kept as low as practicalble and that any unneccessary exposure be avoided.

ICRP Publication 9 (1965)

AS LOW AS READILY ACHIEVABLE (ALARA)

As any exposure may involve some degree of risk, the Commission recommends that any unneccessary exposure be avoided and that all doses be kept as low as readily achievable, economic and social considerations being taken into account.

ICRP Publication 26 (1977)

Three components of the system of dose limitation

1. Justification: No practice shall be adopted unless its introduction produces a positive net benefit.

2. Optimization: All exposure shall be kept as low as reasonably achievable, economic and social factors being taken into account.

3. Dose Limit: The dose equivalent to individuals shall not exceed the limit recommended for the appropriate circumstances by the Commision.

ICRP Publication 60 (1990)

SYSTEM OF RADIOLOGICAL PROTECTION

(1)JUSTIFICATION OF A PRACTICE

No practice involving exposures to radiation should be adopted unless it produced sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes.

ICRP Publication 60 (1990)

SYSTEM OF RADIOLOGICAL PROTECTION

(2)OPTIMIZATION OF PROTECTION

In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should all be constrainted by restrictions on the doses to individuals (dose constraints), or the risk to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgement.

ICRP Publication 60 (1990)

SYSTEM OF RADIOLOGICAL PROTECTION

(3)INDIVIDUAL DOSE AND RISK LIMITS

The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. There are aimed at ensuring that no individual is exposed to radiation risk that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible of control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit.

DOSE CONSTRAINTS(1)
Meaning of Dose Constraints

Dose constraints may be an important tool for improving optimization in practical radiation protection and for facilitating communication between operators, employers and regulatory authorities.

The objective of Dose Constraints is to be a ceiling to the values of individual doses from a source, practice or task which could be determined to be acceptable in the process of optimization of protection for that source, practice or task.

DOSE CONSTRAINTS(2)

♦Dose constraint is the value of individual dose that is expected not to be exceeded in the predicted individual dose distribution resulting from the optimization process.

♦Dose Constraint may be related to the protection of persons against exposures from a complete practice or from any part of a practice which is subject to optimization, i.e. exposure due to:

- a source such as a simple small one, a single machine, or a big installation:
- a set of sources in an installation:
- a paticular task in connection with a source or set of source, or a complete job.

CALCULATION OF DOSE CONSTRAINTS(2)

$$\hat{E}=(E_{limit} - (E_{global} + E_{regional} + E_{reserved}))F$$

where

$\hat{E}$=dose constraint

E_{limit} = dose limit

E_{global} = maximum annual per caput exposures from existing and projected global sources from existing practices

$E_{regional}$ = maximum annual per caput exposures from existing and projected regional and local sources from existing practices

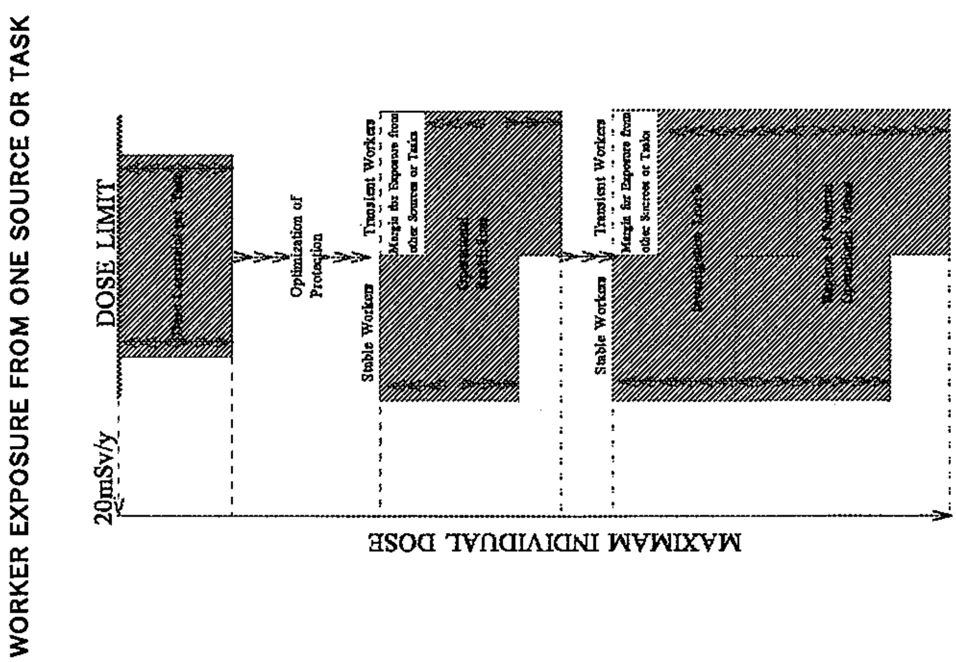
$E_{reserved}$ = allowance for exposures from, as yet, unknown practice

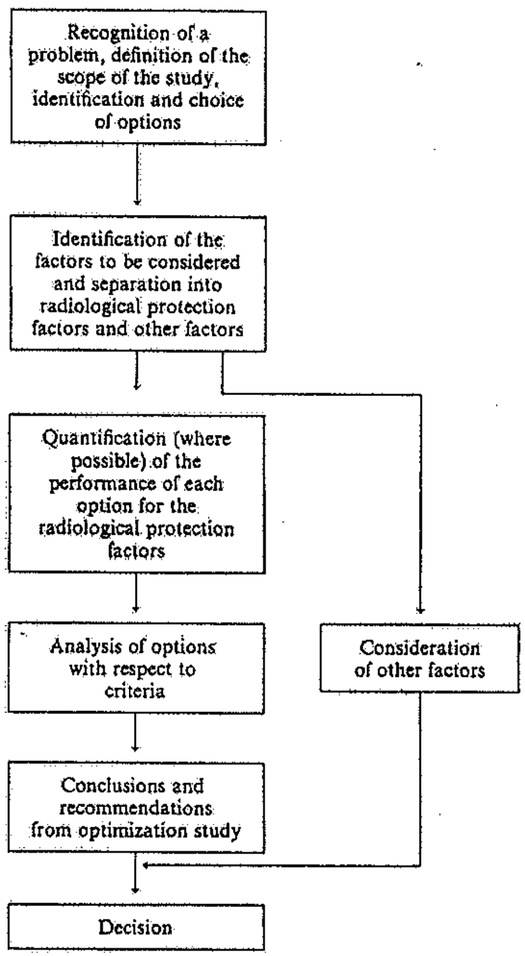
F = factor allowing for a possible inclease in individual exposures due to a change in critical group habits, etc., while the source is operating.

Dose constraints and the practices to which they apply in some member states.(IAEA)

Country	Dose Constraint ($mSv \cdot a^{-1}$)	Practice
Argentina	0.3	Nuclear fuel cycle facilities
Belgium	0.25	Nuclear fuel cycle facilities
Germany	0.3	Nuclear fuel cycle facilities
Italy	0.1	PWRs
Luxembourg	0.3	Nuclear fuel cycle facilities
Netherlands	0.3	Nuclear fuel cycle facilities
Spain	0.25	Nuclear fuel cycle facilities
Sweden	0.1	Power reactors
USSR	0.25	Power reactors
UK	0.5	Effluent releases
USA	0.25	Nuclear fuel cycle facilities

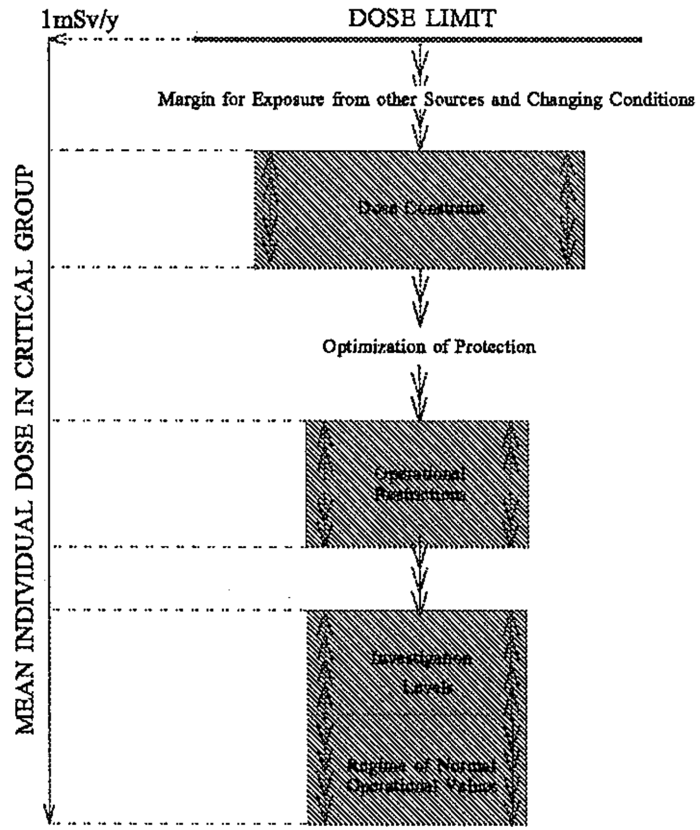
IAEA-TECDOC-664 Establishment of source related dose constraints for menbers of the public.

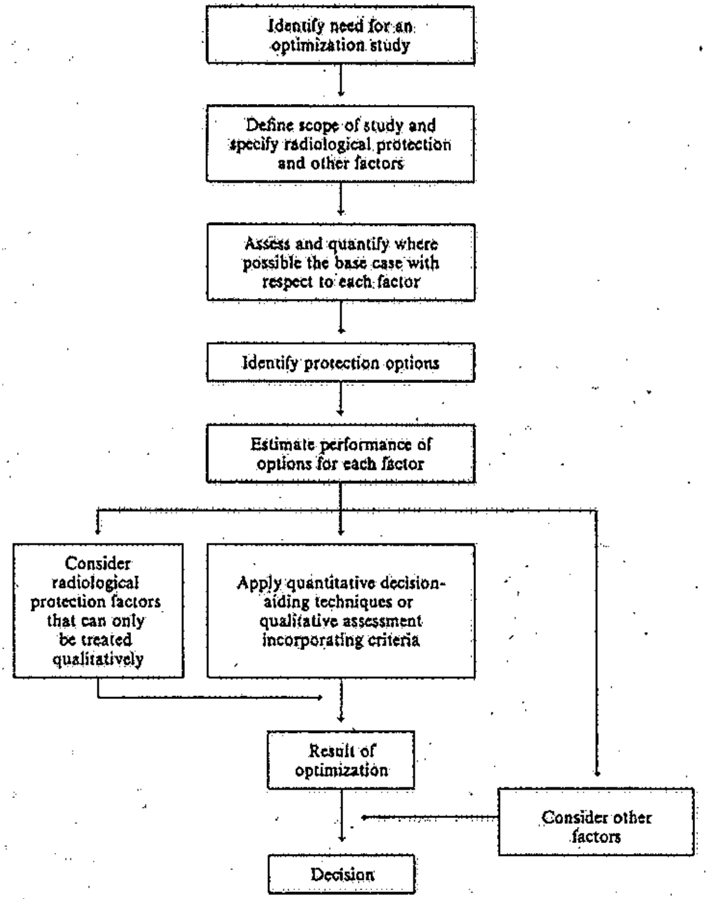




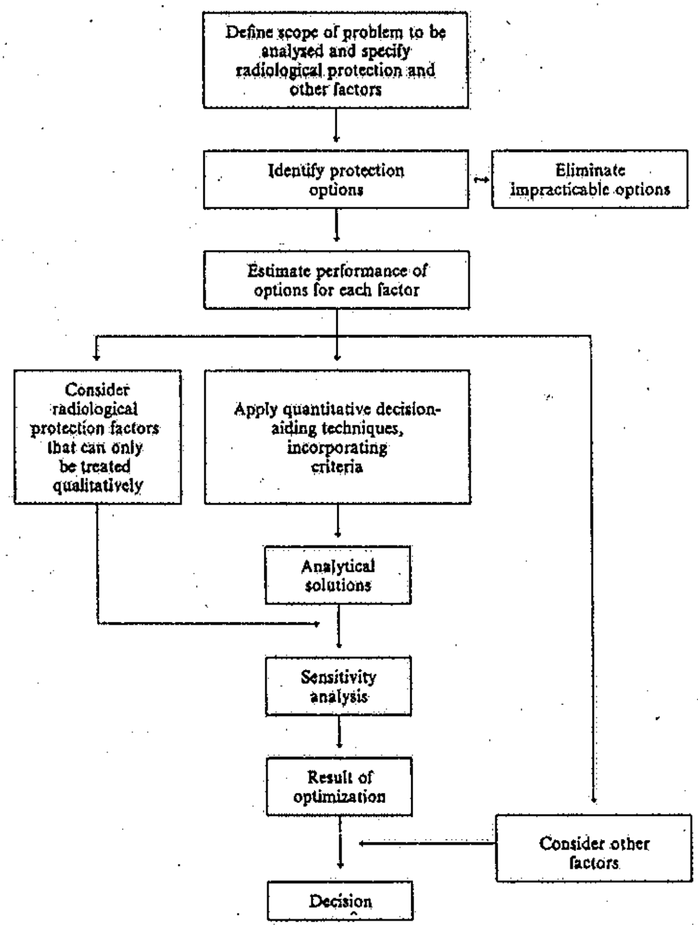
Structured approach to optimization of protection in the context of decision making.

PUBLIC EXPOSURE FROM ONE SOURCE OR PRACTICE





Schematic representation of the optimization procedure applied to operational situations.



Schematic representation of the optimization procedure in design studies.

QUANTITATIVE DECISION-AIDING TECHNIQUES

- ♦ **Cost-Effectiveness Analysis**
- ♦ **Cost-Benefit Analysis**
  (Extended cost-benefit analysis)
- ♦ **Multi-Attribute Utility Analysis**
- ♦ **Multi-Criteria Outranking Analysis**

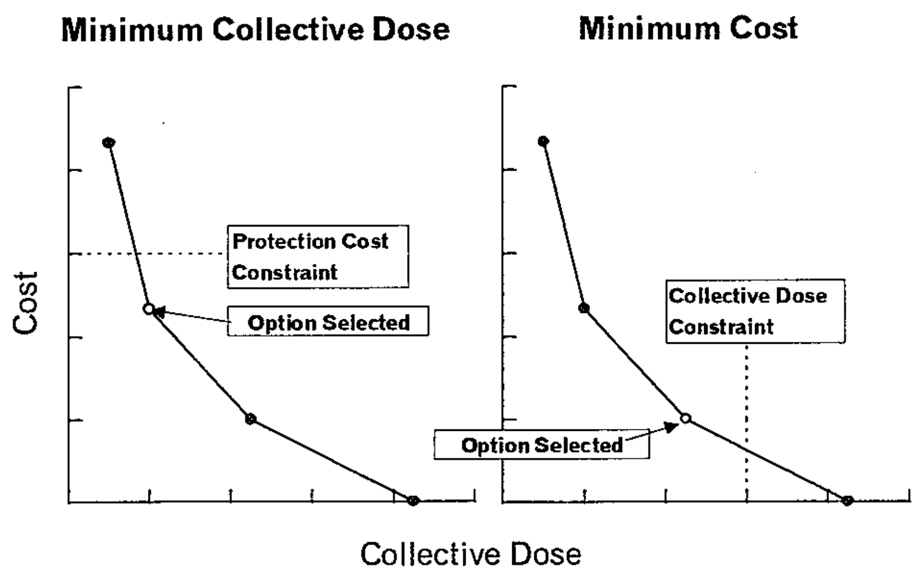
COST-EFFECTIVENESS ANALYSIS

♦**Each option has a level of protection cost and a corresponding collective dose.**

♦**By a simple examination of this analysis, a pre-selection of options based on these two factors can be performed.**

♦**This pre-selection can sometimes be useful but is not enough to define the optimum solution.**

COST-EFFECTIVENESS ANALYSIS



COST-BENEFIT ANALYSIS

♦A principal characteristics of cost-benefit analysis is that the factor influencing a decision are commonly expressed in monetary terms.

♦The focus is on aggregated monetary measures of the costs and benefits associated with options, with the objective being to indentify the option having the minimum aggregate.

♦A simple cost-benefit analysis can be implemented by trans- forming the collective dose into a monetary valuation using the refrence value of unit collective dose, alpha.

APPLICATION OF COST BENEFIT ANALYSIS

♦GENERAL EQUATION

$$B = V - (P + X + Y)$$

where

V = gross benefit of the practice
P = product cost
X = cost of achieving a selected level of protection
Y = cost of radiological detriment at that level of protection

♦Optimization is achieved when the net benefit is maximised with respect to the costs associated with the level of radiation protection.

♦The optimum level of protection is obtained where the general expression X(S)+Y(S) is at minimum.

$$\left(\frac{dX}{ds}\right)_{S^*} + \left(\frac{dY}{ds}\right)_{S^*} = 0$$

S* = collective effective dose equivalents

EXTENDED COST-BENEFIT ANALYSIS

♦The cost-benefit analysis technique is strictly limited to quantitative comparison between the protection cost and the collective dose.

♦To incorporate this judgement, via extended cost-benefit analysis, one method is to modify the value assigned to unit collective dose.

$$Y=\alpha S+\sum_j \beta_j S_j$$

COLLECTIVE DOSE

♦In recent years the use of collective dose has been increasingly a subject of discussion and debate.

♦Problems have arised from the use of collective doses to predict excess numbers of fatalities based on very small doses summed over large population and thousands of years.

♦While the mathematics of the LNT allow the valid summation of such doses over such population and time scale, the interpretation and usefullness of the results have been questioned.

APPLICATION OF OPTIMIZATION

♦The choice of a ventilation system in a small uranium mine. (ICRP 55)

♦Steam generator repair policy. (Switzer land)

♦Maintenamce of pump of primary loop recirculation system. (Japan)

♦Placement of continuous air monitor in Pu plant. (USA)

♦Assessment of design provisions for radiation protection on nuclear power plant. (UK)

♦Shielding optimization for medical electron accelarators. (Germany)

CONTROLLABLE DOSE(1)

R.Clarke (ICRP/NRPB)

Control: control the dose to the representative member of the most highly exposed group.

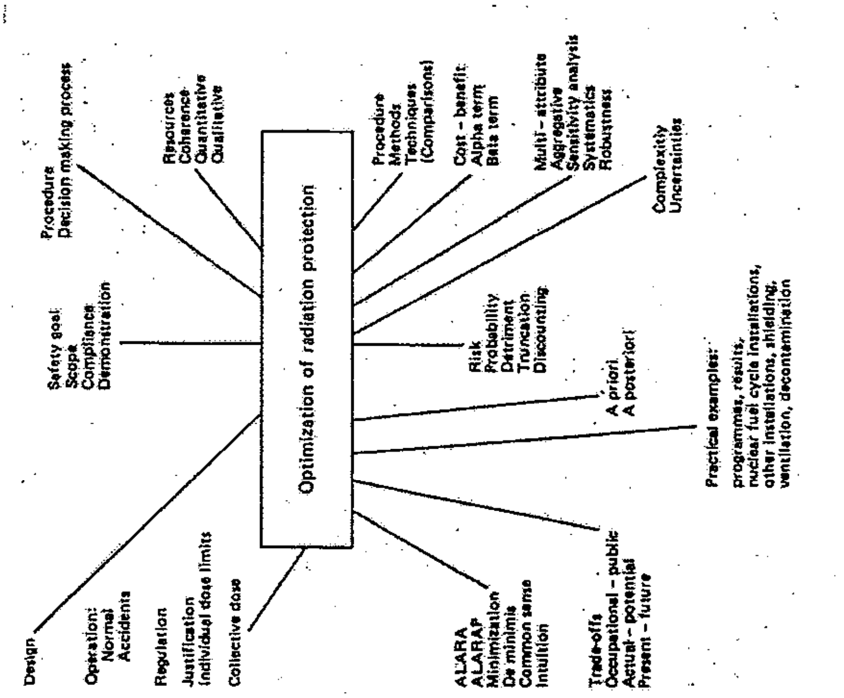
ALARP: ensure that resulting dose is as low as reasonably practicable.

CONTROLLABLE DOSE(2)

This more straight forward single-scale system of protection is consistent with the present system based on acceptable risks, but importantly may be explained to individuals more understandably as multiples or fractions of the natural background. In which case, perhaps there is no need to destroy the credibility of the profession in arguments for or against a threshold.

CONTROLLABLE DOSE

Fatal Risk	Dose μSv	Proposed System	Current Criteria
10^{-3}	30000	Dose should not exceed this level-approach only if there is benefit to individual or dose is difficult to individual	· Occupational dose limit · Upper Rn Action Level · Relocation IL · CT Scan
10^{-4}	3000	There may be a need to reduce or prevent doses, particularly if no benefit to individual	· Lower IL for shelter, KI · Lower Rn Action Level · Average Background · Diagnostic Levels
10^{-5}	300	Maximum dose to individual who receives no direct benefit from one source of radiation	· Maximum constraint from a single source · Background variation - excluding Rn
10^{-6}	30	Trivial risk to the individual	· Exemption Levels · Clearance Levels



Aspects of optimization of radiation protection.

FUTURE DEVELOPMENT

OPTIMIZATION

Practical guidance is needed to better apply the principal of optimization.

COLLECTIVE DOSE

Clear, objective operational guidance for the valid application of collective doses is important.

The Fukui District Court rejected a suit filed by a group of residents calling for the permanent closure of the Monju which is Japan's only prototype fast-breeder nuclear reactor. The district court ruled as follows:

It cannot be denied that the benefits resulting from the operation of the reactor facilities is one of the factors in judging safety. However, the risk or the detriment caused by the operation of the reactor facilities involving release of radioactive substances into the environment is contrary to the legally protected important rewards, such as lives and health of people, which the highest respect shall be shown to. Therefore, the risk or the detriment shall not be compared simply with the benefits resulting from the operation of the reactor facilities. It is no wonder that the risk to the life or health should be required to be lower than the acceptable level to socially; that is, the effects should lower to the extent that they are regarded as a socially negligible level. Namely, it is never acceptable to justify the risk which exceed such level even if the operation of reactor facilities leads the benefits. Therefore, it is necessary that an expected benefits should justify the risk within the level mentioned above, and such benefits are sufficient for the social rewards.....