IAEA
International Atomic Energy Agency

12. The ALARA approach at the design stage (global and detailed approaches)

What about the ALARA approach at the design stage?

- What about optimization at the design stage of a facility?
- What about optimization at the design stage of an intervention?
- What about optimization at the design stage of equipment?
- These are different areas but the ALARA approach should follow the same rules

The two steps of the design optimization (1)

Whatever has to be designed :

- a new facility,
- a new equipment,

a new project (operating, maintaining, modifying,

- dismantling a facility or an equipment),

there are two main steps in implementing the ALARA approach

- 1. The so called "**summary pre-project**" or "**feasibility study**", or "**pre design study**"; whose role is to define the core of the project, selecting between different technical scenarios.
- 2. When the technical scenario is selected, then start the second step with the "**detailed pre-project**" or "**implementation study**".

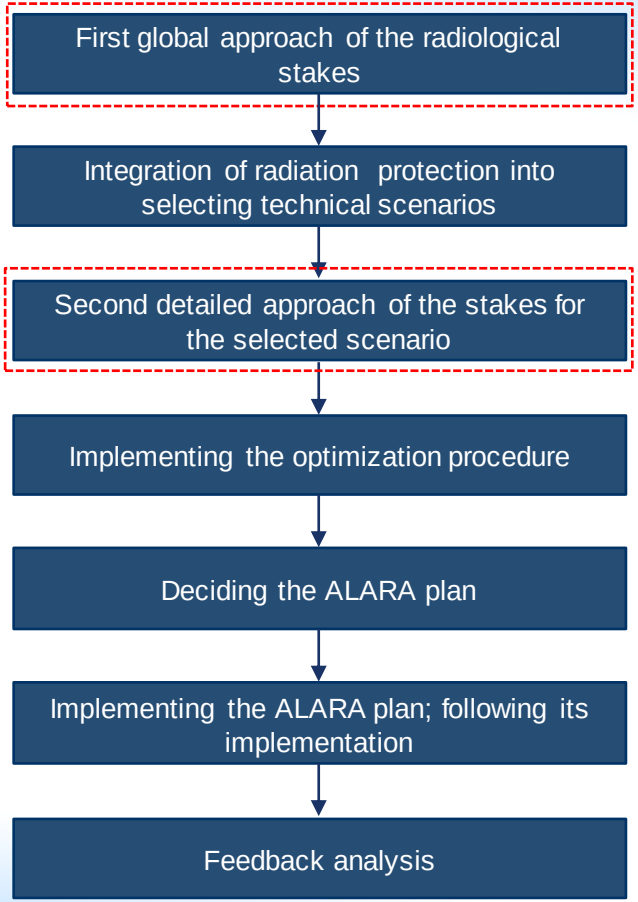
The two steps of the design optimization (2)

In the first step radiation protection is often one among a lot of other criteria for selecting the scenario: at that stage a multi attribute analysis is often the good solution for facilitating the decision; but it remains very important that doses are assessed at that stage and radiation protection is taken into account.

That step can be performed directly for one new utility (operation) in the nuclear field or as a generic study in the medical field.

In the second step the optimization procedure has to be implemented in a more detailed way.

ALARA at the design stage



What happens if the ALARA approach is not implemented enough early at the design stage of a facility?

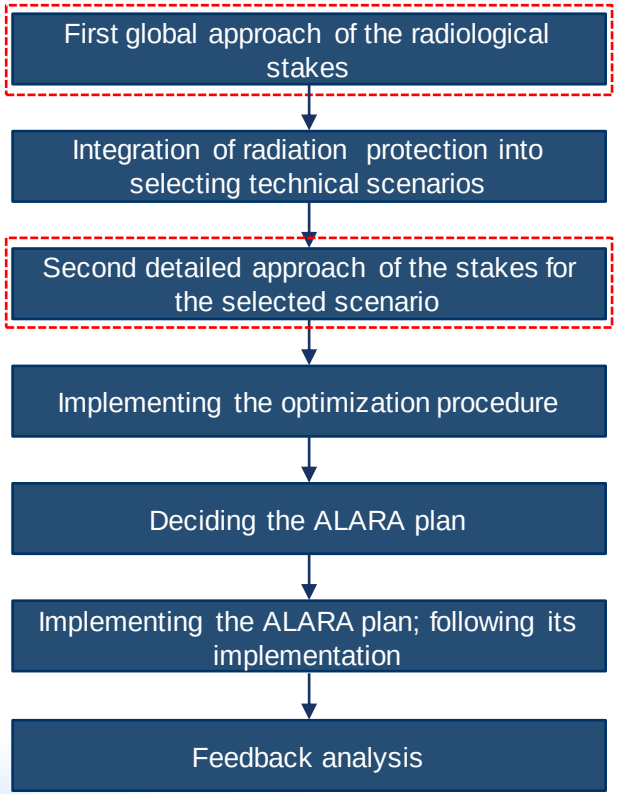
In many cases in the past, occupational radiation protection was taken into account after all parameters had been decided at the latest stage of the design

A plant was designed, a few decades ago, for radioactive wastes treatment. The first dose assessment was performed when the plant was already nearly built.

It appeared then that the collective dose will approach 500 man mSv without guaranteeing to 10 among the 45 workers that they will not exceed the 20 mSv dose limit.

This is why it was finally decided to implement the ALARA approach, but… it was too late for really lowering the doses

ALARA at the design stage



One can say that the plant was built without following any of these phases… neither during the first or the second step of the design study.

First dose assessment for the new built plant…without any ALARA approach

457 man.mSv per year, each year of the plant life , (expected 20 to 30 years), which is not trivial at all.

Mean individual annual dose : 10,1 mSv.

10 workers among 45 being potentially above 20 mSv which is not acceptable in general and even more at the design stage !!

Design individual dose constraint

In order to ensure, in the real future life of the plant (but this could be for a maintenance operation or a dismantling), not to exceeding the dose limit, it is recommended, and this has been done for that optimization study, to set up a dose constraint of 15 mSv.

Therefore all what is necessary to be done for being under 15mSv shall be done whatever the cost; optimization start only when that constraint is respected.

Identifying options and combinations of options

As the plant was already built, the general features of technical process were not too much modifiable but only marginally.

The place where each of the 45 workers works being known, it was then decided to implement the optimization approach for each group of workers working in a specific area.

As ever the first step was a brain storming for imagining all possible dose reduction actions for each group of workers i.e. each group of workplaces.

Here after are the options not “a priori” rejected for two groups of workers.

group of workers number	Options, and options combinations	Description
4 Unloading of radioactive	I	Automation of the unloading process
wastes arriving	J	Installation of a biological shielding
from other facilities	K	Moving away the control desk from the source
7 Exit of the reprocessed	P	Automation reading of the codes bar
wastes	Q	Automation of the barrels taking out
	P+Q	Total automation from the control room

Quantifying dose savings (1)

Group of workers	Combination of options	Number of workers	Indiv. dose before option mSv/year	Individual dose savings Per year mSv	Individual dose after option mSv/year	Collective dose. after option man.mSv/year
	0.Reference	5	4,4	0	4,4	22
4	**I** Automation of the unloading process	5	4,4	2,6	1,8	9
	J Installation of a biological shielding	5	4,4	2,4	2	10
	K Moving away the control desk from the source	5	4,4	2,4	2	10
	0. Reference	1	13,6	0	13,6	13,6
7	**P** Automation reading of the codes bar	1	13,6	4	9,6	9,6
	Q Automation of the barrels taking out	1	13,6	6	7,6	7,6
	P+Q Total automation from the control room	1	13,6	10	3,6	3,6

Quantifying costs (2)

Group of workers	Combination of options	Investment cost k€
	0.Reference	0
4	**I** Automation of the unloading process	30
	J Installation of a biological shielding	18
	K Moving away the control desk from the source	15
	0. Reference	0
7	**P** Automation reading of the codes bar	30
	Q Automation of the barrels taking out	120
	P+Q Total automation from the control room	150

The operating costs have been considered as negligible and no other criterion was needed to make the decision

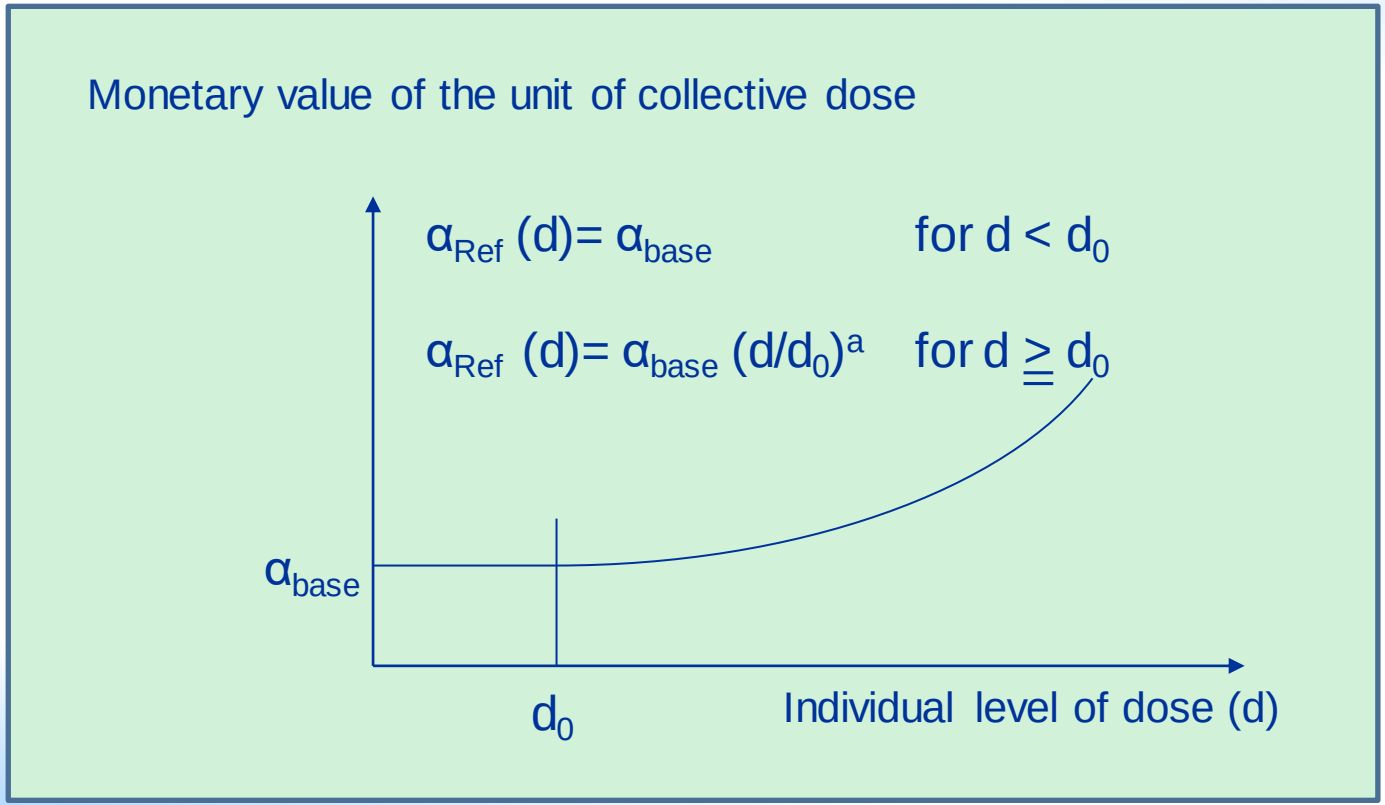
Determining optimal solutions for each group of workers

Therefore it was possible to make use of a decision aiding technique dealing only with the doses and costs and as the annual individual doses were known the selected technique was the cost-benefit analysis.

Cost benefit analysis method:

The optimal option is the one for which the total cost is minimum: i.e. the sum “protection action cost + residual risk cost “ is minimal where the residual detriment cost is estimated as the product of the residual individual dose by the corresponding monetary value of the man Sievert.

Reminder: a model for the man.Sievert monetary value (α) taking care of the risk aversion



Assessing the cost of the detriment (1)

Example of the group 7:

There is a single worker with an annual dose of 13,6 mSv in the reference situation

$\alpha(d) = \alpha_{Base} \cdot (d/d_0)^a$

Here the annual detriment cost of the worker is:

$\alpha(13,6) = 15€ \cdot (13,6/1)^{1,35} = 6\ 917€$

Which means for 20 years: 6 917 . 20 = 138 337€

Assessing the cost of the detriment (2)

exercise:

1. calculate the total cost for reference situation for the group 7 worker

2. write the formula for the detriment for the group 7 worker after the P option

3. write the detriment formula for the group 4 reference

Calculating the total cost for all options and combination

Group of workers number	combination of options	Detriment cost k€	Protection cost k€	Total cost k€	status
4	0.reference	50	0	50	
	I	6	30	36	
	J	8	18	26	
	K	8	15	**23**	**optimum**
7	0. reference	138	0	138	
	P	62	30	**92**	**optimum**
	Q	36	120	156	
	P+Q	6	150	156	

A sensitivity analysis was then performed modifying the life duration of the plant, the alpha value coefficients,… without modifying the results : the optimum remained the same whatever the hypothesis

The final results (1)

After deciding to implement all optimal options

The collective dose remained 316 man.mSv per year (30% decrease)
with a mean individual dose of: 7 mSv/year,
and a maximum individual dose of:13 mSv/year,
and no worker is exceeding the design dose constraint of 15 mSv/year.

The final results (2)

This was eventually better than the reference situation, but:

the degree of freedom being quite small, as the plant was built, the decrease of doses reasonably achievable was not so important and the expected doses remained quite high for a totally new plant.

What would have happened if the optimisation process had started earlier?

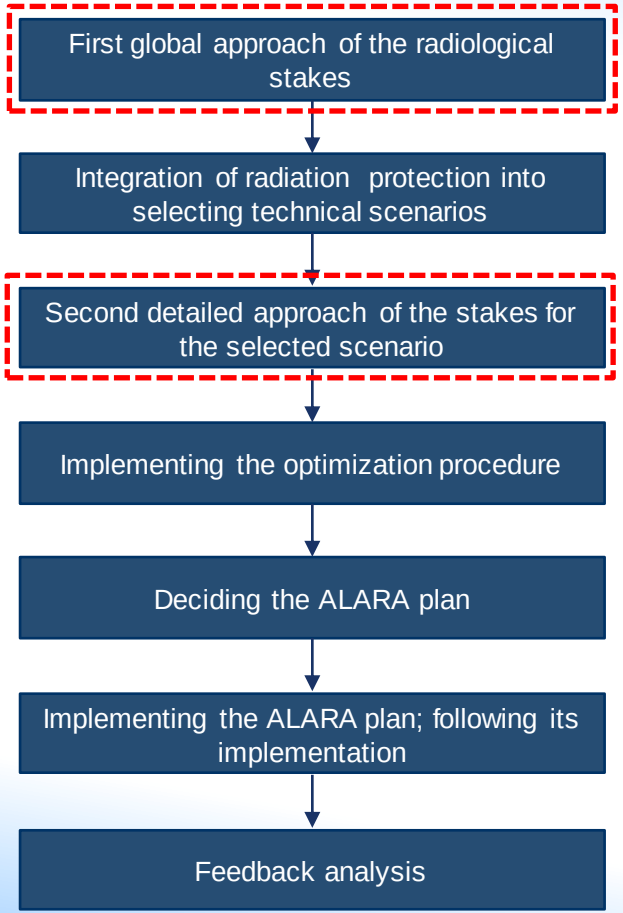
What would have happened ?

All examples we know show that taking radiation protection into account at the design stage of a plant allows very big decreases in expected and actual doses… and often also in other occupational risks and in costs.

This will be illustrated by another example dealing with a modification of a plant.

In that plant there was a need to install a pump on a pipe for accelerating its flow; therefore it was needed to cut a portion of the pipe, to bring the pump, to install the pump, to weld the pump and the pipe and test the welding before testing the good functioning of the pump is quite irradiating.

ALARA at the design stage



Radiation protection was taken into account at the right start of the first step.

Defining scenarios

The dose rates at workplaces had been measured before cutting and assessed after cutting and with the pump in place . They range between 0,5 and 6 mSv per hour. This was not trivial.

Four technical scenarios were envisaged by the engineers from the very beginning of the project making use of different tools for cutting, welding, testing and even bringing the pump.

For each scenario the engineers, with the help of RPO's, made very quickly simple assumptions on the time spent in different areas at different times by the workers for each main action.

A first lesson is then that it is always possible to make crude hypothesis even for a very new situation.

Rough expected doses per scenario

4 scenarios for installing the pump on a pipe

Scenario	EWL. total (hours)	Dose forecast (man.mSv)
No. 1	555	248
No. 2	868	365
No. 3	1012	255
No. 4	600	300

Is it acceptable ?

At that stage

Making a decision on technical and economical criteria would have led to select scenario number 4 (which obviously is not the best in terms of doses)

Taking into account the exposures raised the question:

"is it acceptable to get 300 man.mSv just for installing a pump?"

This was considered as unacceptable by the project leader and the plant hierarchy and the decision was to go back to preliminary to find another technical solution

A new solution to take care of radiation protection

The engineers started another brain storming, not very long, with radiation protection as a priority; they imagine a fifth scenario, technically feasible, remaining in the order of magnitude for the EWL but much more efficient in terms of exposures

- EWL 800 hours
- Expected collective Dose : 85 man.mSv (70 % decrease)

As nothing was started neither the intervention nor the purchase of the tools, it was just brainstorming, the scenario was very easy to modify and costs were very few in comparison with the previous example where it has cost several man years of engineers for the new study and millions of Euros for investing in optimizing the already built plant.

What would have happened ?
An high degree of freedom allows best optimisation

Conclusion :

The less the design study is advanced:

the more the degree of freedom is important for the designer to reduce doses and

the less "taking care" of radiation protection will appear to be an over cost.

What can be done in designing new equipment and tools? (1)

A kind of ALARA check list can be set up here

What can be done for reducing the source

- By modifying the source composition
- Ex: developing industrial radiography devices with Selenium sources instead of Iridium or Cobalt.

What can be done for reducing dose rates to the workers

- 1. By selecting the best solution for source position
  - ex: designing only machines with tube under the table for all interventional radiology, cardiology … procedures = no differential investment cost but big dose decrease
- 2. By providing biological shielding directly on the device
  - ex: table shielding in interventional
- 3. By installing shielding and / or alarms directly on tools or equipment, as on industrial gammagraphy source containers
- …

What can be done in designing new equipment and tools? (2)

What can be done for reducing the EWL?

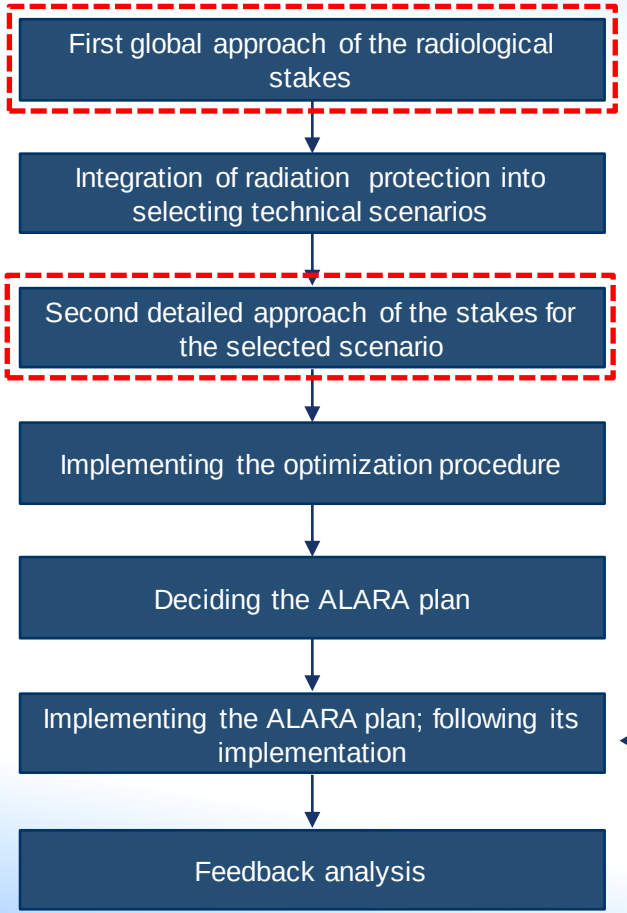
1. By increasing the efficiency of the workers through

- facilitating the use of the tools
- increasing the speed of the tools
- …

2. By reducing the human presence

- increasing the level of remote control /
- increasing automation
- …
- Of course answering all these questions when developing a new device or tool implies knowing the doses when using previous tools or equipment. It always relies on good feedback data and analysis

ALARA at the design stage



Following the implementation of the ALARA plan implies that the vendor (designer) will be involved later on…

To imply the designer /vendor into the operation of a new device

The need for Vendor involvement in optimization was reminded in the recommendations from the 13th European ALARA Network on ALARA and the medical sector (2011)

"When purchasing new machines, the vendor should work with the hospital multidisciplinary team until all protocols are optimized,"

"Vendor should be involved until the team is able to utilize all the optimizing tools available on the machine"