USE OF COST BENEFIT ANALYSIS IN THE FIELD OF INDUSTRIAL RADIOGRAPHY

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INTRODUCTION

Over the past decade NRPB has had a programme of work on the development of cost benefit analysis (CBA) techniques in the optimisation of radiological protection. A provisional framework for including suggestions for assigning a value to unit collective dose was published for consultation in 1981/82 and after various interim statements this process culminated in formal advice in 1986[1]. As part of this work, and as part of a project for the Commission of the European Communities (CEC) the NRPB has carried out a number of case studies to demonstrate the practical implementation of ALARA or optimization of protection using CBA. These techniques, used in conjunction with ALARA Audits, covered in an associated paper[2], are now in general use in the NRPB's Radiation Protection Adviser Service. They have been used for a variety of medical and industrial situations, but mainly in industrial radiography as this is the part of the non-nuclear sector where occupational exposure problems predominate. The three cases below are given as representative examples.

CASE 1 : DESIGN OF AN X-RADIOGRAPHY FACILITY

This was an 'a posteriori' study[3] of how optimisation considerations might have provided an input to the design of an existing X-radiography facility (see Fig. 1).

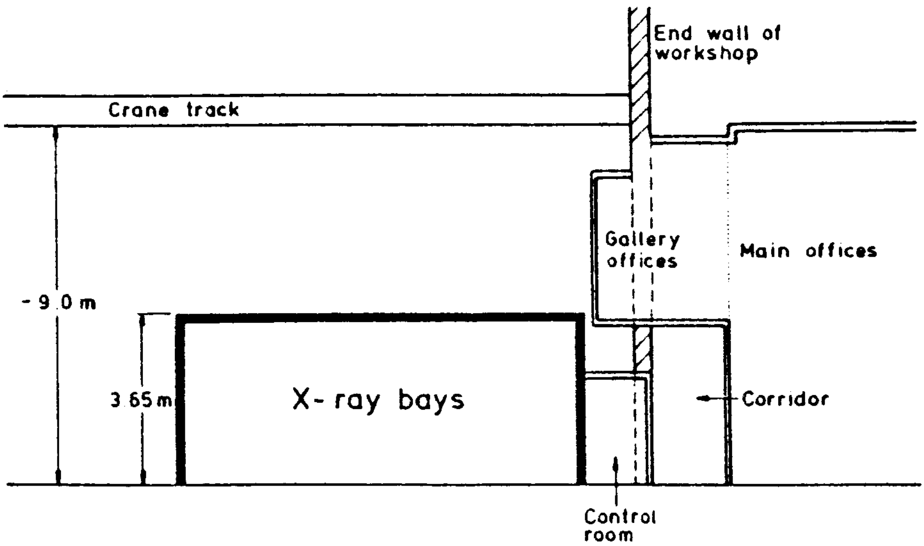

Figure 1 Elevation view of radiography facility

The facility consisted of twin adjacent bays situated within a factory workshop, designed to each accommodate a 200 kVp, 5 mA directional X-ray set used to radiograph a variety of pipework. The useful beam could be pointed in all directions at or below the horizontal. The facility was built from lead sheets affixed to a steel framework. The walls were 7 mm thick lead, designed to ensure that under the worst possible condition of operation the external dose rate would not exceed 7.5 $\mu Sv.h^{-1}$. There were sliding roofs to permit the cranage of workpieces and to protect the overlooking offices during use. The roofs incorporated 4 mm thick lead.

It was decided to limit the problem to optimising the wall thicknesses, using steps of 0.5 mm of lead, and to analyse the protection options of no roof, a shielded roof and a shield on the front face of the gallery offices. Although judgments on the allocation of overhead costs and maintenance costs had to be made, it was relatively easy to identify the protection costs for each protection option. These were in 1980 prices and to cover temporal distributions the costs were annualised over an assumed 20 year useful life using a 5% discount figure. To cost the detriment, the NRPB's provisional costing framework was used and required assessments of the individual and collective doses arising for each protection option. This had previously not been assessed and required modelling of the work pattern, associated dose rate distribution and occupancy distribution, taking into account both transmitted and airscatter radiation. As well as a realistic model reflecting the best estimates of dose, a 'design capacity' model to reflect future changes in work patterns was produced and used.

A cost benefit analysis was carried out using both total cost and incremental cost methods. The technical solution, or 'ALARA solution' was that for the realistic and design capacity models, the optimum wall thicknesses were 2.25 and 3.0 mm lead respectively. Also, for both models the optimum solution for the roof was to dispense with the shielded roof, but to provide a shield to the front of the offices. The sensitivity of these conclusions to variations in a wide range of parameters was tested and the results were found to be robust with variations not exceeding 0.5 mm lead thickness in the walls.

The study used the structured approach of the ALARA procedure developed by Webb et al[4]. In this a clear distinction is made between the ALARA solution and the final decision. It requires identification of factors which can be quantified and included in the analysis and other factors that are relevant to the decision maker but which cannot be quantitatively included. In this case the latter included regulatory factors, reaction of the workforce and accident scenarios. Where there is a quantitative element to factors not directly included in the analysis it is useful for these data to be made available to the decision maker. In this instance for each protection option the following data were supplied: capital cost penalty for shielding to greater than the optimum, maximum individual dose, the maximum instantaneous and time averaged (over 8 hours) dose rates. The latter would be relevant to avoiding the regulatory need for establishing a controlled area outside the X-ray rooms.

CASE 2 : LOCAL SHIELDING FOR GAMMA RADIOGRAPHY

The second case was an 'a priori' study that arose out of a protection problem identified by an ALARA Audit(2). Within an open top radiography facility inside a workshop, the Company carried out gamma radiography of steel pipework using an Ir-192 source of 185 GBq maximum activity. It was always used without collimation, i.e. panoramically, either inside a pipe for circumferential welds or external to pipes in double wall single image (DWSI) methods. Assessment of the doses involved indicated annual collective doses of 33 and 11.4 man.mSv associated with the DWSI and circumferential methods, respectively. Local shielding in the form of a directional collimator (for DWSI) and a 360° collimator and/or a shielding 'saddle' (circumferential) were considered as protection options. The collimators were commercially available but the shielding saddle would have to be purpose-built and would require to be craned into position. Experience suggested that the collimators, particularly for the DWSI work would be cost effective, but the option of the saddle was not so clear. Therefore it was decided to carry out a simple cost benefit analysis (shown in Table 1) to act as an input to the decisions. A useful life of 10 years was assumed for each option and 0% discount was used.

Date and Element of Analysis	Protection Step			
	DWSI	Circumferential		
	Base Case to Collimator	Base Case to Collimator	Base Case to Saddle	Collimator to Collimator and Saddle
Incremental Cost (£)	500	500	1000	1000
10y dose savings (man mSv)	287	76	86	29
Incremental Cost Effectiveness (£/man Sv)	1.7k	6.6k	11.6k	35k

The annual individual doses were initially of the order of 1 mSv and using the most recent NRPB advice(1) a figure of £15,000 per man Sv was considered appropriate. This analysis therefore confirmed that the collimators were cost effective. The use of the saddle (after implementing the collimator option) would not appear to be cost effective, but possible variations in parameters such as doubling the useful life would make the option more desirable. Also there were other inputs to the decision which were not quantified, e.g. additional production costs due to cranage and advantages from its use in another area of work, open shop radiography. Overall the decision maker decided to implement the saddle option.

CASE 3 : TORCH TYPE CONTAINERS

For many years 'torch' type containers have been used in industrial radiography. These require manipulation of typically 0.4 TBq Ir-192 on the end of a shielded 30 cm 'torch'. They require proximity of the operator and in many cases have been gradually replaced with remote exposure containers, the use of which gives rise to significantly lower doses. The introduction of new Regulations placed more emphasis on ALARA and caused two Companies to consider whether or not it would be reasonably practicable to replace their existing torch containers with remote exposure containers. Table 2 provides a summary of the results from a cost-benefit analysis of these two situations.

Table 2

	No. of workers	Individual dose range (mSv)	Annual Collective dose (manSv)	10 y dose saving (manSv)	Protection cost (£)	Cost Effectiveness (£/manSv)
A	4	0.4 - 2.7	0.007	0.07	7.0k	100k
B	12	5.0 - 18	0.13	1.3	38k	30k

The NRPB advice[1] recommended a general figure of £15k/man.Sv for occupational exposure to cover the objective health detriment and individual risk aversion. However, it specifically recommended an additional multiplier where individual doses were a significant percentage of the dose limit. For Company A the individual doses were small (due to a low workload) and thus £15k/man.Sv was the appropriate figure to compare with the incremental cost effectiveness. For Company B the doses are a significant percentage of the dose limit and indeed would have been above the ALARA Investigation Level of 15 mSv. At this dose level an extra multiplier of 5 was considered appropriate giving £75k/man.Sv. It was concluded that for Company A it was not reasonably practicable for them to purchase remote exposure containers until the end of the useful life of the torch containers. However, for Company B it was concluded that in order to achieve ALARA, investment in the new containers should be made.

REFERENCES

1. NRPB, Cost benefit analysis in the optimisation of radiological protection. Chilton ASP-9.

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4. Webb et al, Development of a general framework for the practical implementation of ALARA, Vienna 10-14 March 1986.