CHAPTER 7
ESTIMATING THE COSTS OF A MAINTENANCE PROGRAMME

7.1 Introduction

In Chapter 6 we considered how to prepare maintenance strategy options and programmes to achieve the target level of service and the efficient physical utilisation of major resources. This process will normally result in several balanced programme options, one corresponding to each strategy option, as shown in Figure 6.1.

The final selection of the maintenance strategy will depend on a cost criterion: minimisation of the life cycle cost over the planning period. In this chapter we consider how to estimate this life cycle cost, and the setting of maintenance budgets, as already outlined in Figure 6.1.

The chapter is divided into the following sections:

- identification of inputs and input costs for each task
- estimation of annual costs for a particular programme over the extended planning period
- calculation of the present value of the costs, and hence the annualised costs, over the extended planning period.

In Chapter 8 we then use this approach to compare the costs of different maintenance strategy options.

7.2 Identification of the inputs and estimation of input cost for each task

There are several steps to be taken in determining the inputs required to fulfil a maintenance programme:

- identification of the maintenance requirements (Chapter 5);
- quantification of the productivity of selected control methods (Chapter 6);
- specification of the maintenance programme (Chapter 6);
- scheduling the inputs required to fulfil the specified maintenance programme (Chapter 6).

The information generated at each stage of the process ultimately enables the calculation of the costs associated with the specified maintenance programme. In defining the costs, annual input requirements should be calculated over an extended planning period.

Following the specification of a maintenance programme, it is necessary to determine the inputs required to fulfil the programme. These will vary according to the nature of the control methods adopted in the programme. For example, at the simplest level, labour and hand-tools might be the only inputs required to maintain a channel (or hierarchy of channels). Conversely, if the use of mechanical equipment is a component of a maintenance programme, then the list of inputs will be more extensive and will include all items relating to operation and maintenance of the machinery (e.g. fuel and repairs). In the case of mechanical equipment, manufacturers often produce handbooks giving guidance on the estimation of operating costs of equipment, including figures for the rates of fuel and lubricant consumption. Alternatively, hourly or daily charge rates could be used if available (e.g. hire rates, or charge rates set by the irrigation agency or a government department). These simplify the calculations, but we have taken a more fundamental approach here, to show cash flow in the common situation where equipment has to be purchased.

Initially, input requirements should be determined on a unit basis (e.g. per kilometre of secondary canal) and then total input requirements for a specified programme can be calculated at a later stage. Allied to the identification of inputs is the quantification of input costs. Likewise, these should be expressed as unit costs. Tables 7.1 to 7.3 detail the information required on inputs associated with different methods of weed control.

Table 7.1 Information required on inputs for different methods of weed control.

Information Required		**Method of Control**				
Input	**Unit Cost/Measure**	**Manual**		**Chemical**		
	(Costs in local currency)	Hand-held tools	Boom	Knapsack sprayer	Weed wipe	Boat
Capital cost of equipment & materials						
Hand tool	Cost per tool	✓				
Knapsack sprayer	Cost per sprayer			✓		
Weed wipe	Cost per wipe				✓	
Boat[a]	Cost per boat					✓
Herbicide	Cost per litre			✓	✓	✓
Protective clothing	Cost per outfit per labourer	✓		✓	✓	✓
Boom	Cost per metre		✓			
Application rate/use						
Herbicide	Litres per hectare			✓	✓	
Machine utilisation	Annual operating hours per machine					✓
Insurance						
Cost	Annual cost per machine					✓
Road tax						
Cost	Annual cost per machine					
Fuel						
Consumption	Litres per hour					✓
Cost	Cost per litre					✓
Lubricants						
Consumption	Litres per hour					✓
Cost	Cost per litre					✓
Filter allowance	Percentage of hourly lubricant cost					✓
Repair costs						
Labour	Cost per hour	✓	✓	✓	✓	✓

Parts/materials						
Hand-tool		✓				
Knapsack sprayer				✓		
Weed wipe					✓	
Boat[a]						✓
Boom			✓			
Life of equipment/materials						
Hand tool	Years	✓				
Knapsack sprayer	Years			✓		
Weed wipe	Years				✓	
Boat[a]	Years					✓
Protective clothing	Years	✓		✓	✓	✓
Boom	Years					✓
Labour rates						
Labourer	Cost per hour	✓	✓			
Knapsack sprayer	Cost per hour			✓	✓	
Machine operator	Cost per hour					✓
Mechanic	Cost per hour					✓
Watchman	Cost per hour					✓
Allowance for overheads	(See text)	✓		✓	✓	✓
Productivity of control method	Metres per hour	✓	✓	✓	✓	✓
Frequency of treatment	Number of treatments per year	✓	✓	✓	✓	✓

[a] Inclusive of tanks, spray booms, etc.

Table 7.2 Information required on inputs for mechanical weed control.

Information Required		Mechanical Control					
Item	**Measure**	**Cutting/Harvesting**			**Dredging**		
	(Costs in local currency)	Hydraulic Excavator	Tractor	Boat	Hydraulic Excavator	Tractor	Boat
Capital cost of equipment							
Excavator	Cost per machine	✓			✓		
Tractor	Cost per machine		✓			✓	
Boat[a]	Cost per machine			✓			✓
Grenadier	Cost per machine		✓			✓	
Mowing bucket	Cost per bucket	✓	✓				
Dredging bucket	Cost per bucket				✓°	✓	
Machine utilisation	Annual operating hours per machine	✓	✓	✓	✓	✓	✓
Insurance cost							
Excavator	Annual cost per machine	✓			✓		
Tractor	Annual cost per machine		✓			✓	
Boat	Annual cost per machine			✓			✓
Grenadier	Annual cost per machine		✓			✓	
Mowing bucket	Annual cost per bucket	✓	✓				
Dredging bucket	Annual cost per bucket				✓	✓	

Road tax cost							
Excavator	Annual cost per machine	✓			✓		
Tractor	Annual cost per machine		✓			✓	
Fuel							
Consumption							
Excavator	Litres per hour	✓			✓		
Tractor	Litres per hour		✓			✓	
Boat	Litres per hour			✓			✓
Cost	Cost per litre	✓	✓	✓	✓	✓	✓
Lubricants							
Consumption							
Excavator	Litres per hour	✓			✓		
Tractor	Litres per hour		✓			✓	
Boat[a]	Litres per hour			✓			✓
Grenadier	Litres per hour		✓			✓	
Mowing bucket	Litres per hour	✓	✓				
Cost	Cost per litre	✓	✓	✓	✓	✓	✓
Filter allowance	Percentage of hourly lubricant cost	✓	✓	✓	✓	✓	✓
Tyre costs	Cost per tyre	✓[b]	✓		✓[b]	✓	
Repair costs							
Labour	Cost per hour	✓	✓	✓	✓	✓	✓
Parts/materials							
Excavator		✓			✓		
Tractor			✓			✓	
Boat[a]				✓			✓
Grenadier			✓			✓	
Mowing bucket		✓	✓				
Dredging bucket					✓	✓	
Life of equipment							
Excavator	Years	✓			✓		
Tractor	Years		✓			✓	
Boat[a]	Years			✓			✓
Grenadier	Years		✓			✓	
Mowing bucket	Years	✓	✓				
Dredging bucket	Years				✓	✓	
Tyres	Years	✓[b]			✓[b]		
Labour rates							
Machine operator	Cost per hour	✓	✓	✓	✓	✓	✓
Mechanic	Cost per hour	✓	✓	✓	✓	✓	✓
Watchman	Cost per hour	✓		✓	✓		✓
Allowance for overheads	(See text)	✓	✓	✓	✓	✓	✓
Productivity of control method	Metres per hour	✓	✓	✓	✓	✓	✓
Frequency of treatment	Number of treatments per year	✓	✓	✓	✓	✓	✓

[a] Inclusive of hydraulic arms and cutting blades or dredging buckets, etc.
[b] Wheeled excavators only.
[c] If not supplied with excavator.

Table 7.3 Information required on inputs for environmental/biological weed control.

Information Required		Method of Control					
Item	**Measure**	**Environmental**			**Biological**		
	(Costs in local currency)	Shading	Burning	Water levels	Competitive plants	Herbivorous fish	Herbivorous insects
Capital cost of materials/biological agents							
Hand-tools	Cost per tool	✓	✓		✓	✓	
Shading plants/materials	Cost per plant/metre	✓					
Competitive plants	Cost per plant				✓		
Herbivorous fish	??					✓	
Herbivorous insects	??						✓
Containment structures	Total capital cost					✓	
Additional costs							
Licence	Annual cost		✓			✓	✓
Stocking rates/application rate	Number of biological agents per metre	✓			✓	✓	✓
Maintenance/repair costs							
Labour	Cost per hour	✓			✓	✓	
Parts/materials							
Shading materials		✓					
Containment structures						✓	
Life of materials/biological agents							
Hand-tools	Years	✓	✓		✓	✓	
Shading plants/materials	Years	✓					
Competitive plants	Years				✓		
Herbivorous fish	Years					✓	
Herbivorous insects	Years						✓
Containment structures	Years					✓	
Labour rates							
Labourer	Cost per hour	✓	✓	✓	✓	✓	
Consultant	Cost per hour					✓	✓
Watchman	Cost per hour					✓	
Specialist staff	Cost per hour					✓	✓
Allowance for overheads	(See text)					✓	✓
Productivity of control method	(See text)	✓	✓		✓		
Frequency of treatment	(See text)	✓	✓	✓	✓	✓	✓

7.3 Estimation of the input costs associated with the specified maintenance programme

The total costs associated with specified maintenance programmes can be calculated once the information detailed in Section 7.2 has been obtained. The process is illustrated by an example drawn from our experience at Mwea Irrigation Settlement Scheme, Kenya (Mwea ISS, as described in Chapter 2).

7.3.1 Identification of the maintenance operations

Based on the climatic, agricultural and labour constraints at Mwea ISS, the maintenance programme includes dredging of primary and secondary canals (90 km total length) every year between January and March. In addition, to meet irrigation objectives, the entire length of these channels is manually cut on two occasions, in June and September.

Thus, the maintenance operations are as follows:

- to dredge 90,000 m of primary and secondary channels in three months;
- to manually cut 90,000 m of primary and secondary canals in June and September.

7.3.2 Estimation of the productivity of selected control methods

The estimated average output for mechanically dredging primary and secondary canals at Mwea ISS is 50 m of channel per hour[1].

The estimated average output for manually cutting primary and secondary canals at Mwea ISS is 50 m of channel per labourer per day.

7.3.3 Unit costs of the inputs required to fulfil the maintenance operations

The inputs required to fulfil the maintenance tasks on primary and secondary canals are classified in Table 7.4. The unit costs associated with the inputs are also quantified in the table, expressed in constant prices (local currency in 1994).

For each of the maintenance tasks specified (mechanical dredging and manual cutting), there are associated fixed costs and recurrent costs. The fixed costs are the capital costs of machines (hydraulic excavators) or equipment (i.e. the tools) whilst the recurrent costs are those costs incurred in operating and maintaining the machines or equipment (e.g. labour, fuel and parts). For simplicity here the recurrent costs are assumed constant from year to year, at the average levels as recommended by the manufacturer.[2]

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[1]This figure is based on average productivities of a Komatsu PC200-5 hydraulic excavator with a 0.7 m^3 bucket and a Komatsu PC100-3 hydraulic excavator with a 0.4 m^3 bucket, both operating over a range of conditions.

[2]In practice there will be an increase in repair costs as equipment nears the end of its life

Table 7.4 Classification of the inputs required to fulfil maintenance operation on primary and secondary canals at Mwea ISS.

Maintenance operation	Inputs	Input cost per unit (KSh)	
Mechanical dredging	Hydraulic excavator	9,000,000.00	per machine [a]
	Insurance	752.63	per year [b]
	Road tax	1,500.00	per year [b]
	Fuel	21.90	per litre [b]
	Lubricants, grease, filters		
	Engine oil	76.18	per litre [b]
	Transmission or swing machinery oil	76.18	per litre [b]
	Final drive oil	76.18	per litre [b]
	Hydraulic oil	93.40	per litre [b]
	Grease	86.95	per kilogram [b]
	Filter allowance (50 % total hourly lubricant cost)	10.56	per hour [c]
	Repairs		
	Parts	92.90	per hour [d]
	Labour	17.75	per hour [d e]
	Operator	14,556.00	per year [f]
	Watchman	12,036.00	per year [f]
Manual cutting	Hand-tools	120.00	per tool [b]
	Labourer	33.42	per day [f]

[a] unit cost, based on Komatsu PC200-5 supplied by Panafrican Equipment, Nairobi, October 1994.
[b] unit costs supplied by National Irrigation Board, Mwea, 1994.
[c] filter allowance recommended by Komatsu (1994).
[d] hourly requirements for parts and labour recommended by Komatsu (1994).
[e] unit cost of labour supplied by National Irrigation Board, Mwea, 1994.
[f] unit costs based on Casual Workers Salary Amendment and Agricultural Industry Order Number: 1994 Legal Notice Number 162, supplied by National Irrigation Board, Mwea, 1994.

In most instances it is appropriate to combine all the recurrent cost items associated with a machine and express recurrent costs as a single figure. Table 7.5 illustrates the calculation of annual recurrent costs for a hydraulic excavator. In this case, the machine utilisation is assumed to be 1,500 hours per year.

Table 7.5 Annual recurrent costs for a Komatsu PC200-5 hydraulic excavator.

Input	Unit cost (KSh)	Number of units required	Annual sub-total (KSh)
Insurance	752.63	1	752.63
Road tax	1,500.00	1	1,500.00
Fuel[a]	21.90	12.5 l h^{-1}; 1500 h y^{-1}	410,625.00
Lubricants, grease, filters			
Engine oil[a]	76.18	0.076 l h^{-1}; 1500 h y^{-1}	8,685.00
Transmission or swing machinery oil[a]	76.18	0.009 l h^{-1}; 1500 h y^{-1}	1,035.00
Final drive oil[a]	76.18	0.008 l h^{-1}; 1500 h y^{-1}	915.00
Hydraulic oil[a]	93.40	0.085 l h^{-1}; 1500 h y^{-1}	11,910.00
Grease[a]	86.95	0.07 kg h^{-1}; 1500 h y^{-1}	9,135.00
Filter allowance (50% total hourly lubricant cost)[b]	10.56	1 unit/hr; 1500 h y^{-1}	15,840.00
Repairs			
Parts	92.90	1 unit/hr; 1500 h y^{-1}	139,350.00
Labour	17.75	1 unit/hr; 1500 h y^{-1}	26,625.00
Operator's annual wage	14,556.00	1	14,556.00
Watchman's annual wage	12,036.00	5	60,180.00
Total annual recurrent cost			**701,108.63**

[a] rates for hourly consumption supplied by Komatsu (1994).
[b] filter allowance recommended by Komatsu (1994).

7.3.4 Estimation of the resources required and input costs associated with the specified maintenance programme

The resources required in this example are hydraulic excavators, handtools and labour. It is necessary to consider the number of each required for the maintenance programme, and estimate their capital and recurrent costs. The procedures are illustrated in Sections 7.3.4.1 to 7.3.4.3[3]. In addition, provision must be made for overheads. These include the costs of management and supervision, payments, office and workshop facilities, and any surplus which the operation is required to make (e.g. to contribute to central overheads). Provision for overheads is usually made by adding a percentage (e.g. 20%) to the calculated input costs.

[3] ideally these sections would be formatted as boxes

7.3.4.1 Hydraulic excavators - number required and costs

7.3.4.1.1 Unit cost of excavator

In the present example, the capital cost of the hydraulic excavator, including import duties, is taken to be KSh.9,000,000 (Panafrican Equipment, Nairobi 1994). The annual number of operating hours for such a machine is assumed to be 1,500 and the working life of the machine is assumed to be 10,500 hours. Thus, for this maintenance programme, capital investment in hydraulic machinery is required every seven years.

7.3.4.1.2 Number of excavator units required

The total number of excavators required in order to fulfil the desilting activity in the specified time is a function of the productivity of the machine and the number of machine operating hours. The total number of excavators required can be calculated as follows:

Operation	To mechanically dredge 90,000m of main and branch canals within a period of 3 months
Average output for mechanical dredging (National Irrigation Board, Mwea, 1994)	50m length of main or branch canal per hour.
Number of excavator hours required to mechanically dredge 90,000m of main and branch canals	$\frac{90,000}{50}$ = 1800 hours
Standard number of operating hours for one excavator in a three month period, based on a 6 hour working day and 26 working days per month (National Irrigation Board, Mwea, 1994)	6 x 26 x 3 = 468 hours
Average rate of excavator utilisation	*c*. 80 %
Average number of operating hours for one hydraulic excavator in a three month period (Note that this is equivalent to 1,500 hours per year)	468 x 80 % = 374 hours
Total number of excavators required to mechanically dredge 90,000 m of main and branch canals within a three month period each year	$\frac{1,800}{374}$ = 4.8 = 5 excavators

7.3.4.1.3 Input cost of excavators for this maintenance programme

Although a total of five hydraulic excavators is required in order to dredge primary and secondary canals at Mwea ISS, the excavators are only required for three months each year. The 80% utilisation rate includes an allowance for the time required for servicing and repairs. For the remaining nine months the excavators are assumed to be used elsewhere, for example, on other maintenance or construction work. This is an important assumption, which has a major impact on the costs and therefore must be treated with care. On many irrigation schemes hydraulic equipment will be idle for at least part of the year, so the share of capital cost attributable to maintenance will be greater than the part of the year during which it is used. (For an example of this, see Section 7.3.4.2 on handtools where the whole cost is assigned to the maintenance programme.) In calculating the capital input cost of hydraulic excavators for desilting primary and secondary canals in our example we apportion only one quarter of the total capital cost. Thus, the capital input cost of the hydraulic excavators is calculated as follows:

Capital cost of five PC200-5 hydraulic excavators	KSh.9,000,000 x 5 = KSh.45,000,000
Number of months excavators employed dredging main and branch canals in Year 1	3 months
Capital cost attributable to main and branch canals	KSh.45,000,000 x $\frac{3}{12}$ = KSh.11,250,000

Therefore a capital cost of KSh.11,250,000 will be incurred by the maintenance programme in each of Years 1, 8, 15 etc.

7.3.4.1.4 Hydraulic excavators - annual recurrent costs

In this example, the recurrent input costs associated with a single hydraulic excavator were calculated to be KSh.701,108.63 per year at 1994 prices (see Table 7.5).

In accordance with the premise that only one-quarter of the capital cost of the hydraulic excavators should be assigned to the desilting of primary and secondary canals, it is appropriate to allot the same proportion of the annual recurrent costs of the hydraulic excavators to the maintenance activity. This can be calculated as follows:

Annual recurrent costs of five hydraulic excavators	KSh.701,108.63 x 5 = KSh.3,505,543.15
Number of months excavators employed dredging main and branch canals	3 months
Annual recurrent costs attributable to main and branch canals	KSh.3,505,543.10 x $\frac{3}{12}$ = KSh.876,385.79

Therefore recurrent cost of KSh.876,385.79 will be incurred by the maintenance programme each year.

7.3.4.2 Hand-tools (panga) - number required and capital cost

7.3.4.2.1 Unit cost of hand-tool

In the present example, the capital cost of each hand-tool (a panga or machete) is taken to be KSh.120.00 (East African Seed Company, Nairobi 1994). The hand-tools are assumed to have a working life of ten years. Thus, in this case, capital investment in hand-tools is required after every ten years.

7.3.4.2.2 Number of hand tools required

The total number of hand-tools required for manually cutting weed in primary and secondary canals at Mwea ISS depends upon the productivity of manual cutting. The figure is calculated as follows:

Operation	To manually cut 90,000 m of main and branch canals within a period of 30 days.
Average daily output for manual cutting (National Irrigation Board, Mwea, 1994)	50m length of main or branch canal per day
Number of labour days required to manually cut 90,000 m of main and branch canals	$\frac{90,000}{50}$ = 1,800 days
Number of labourers required to manually cut 90,000 m of main and branch canals within 30 days	$\frac{1800}{30}$ = 60 labourers
Number of hand tools required	60 tools

7.3.4.2.3 Input cost of hand tools for this maintenance programme

In total, 60 hand-tools are required for manually cutting primary and secondary canals. Assuming that any productive use elsewhere is negligible, the whole capital cost of the-tools should be allotted to the maintenance activity. This is KSh.120 x 60 = KSh.7,200. This cost will be incurred by the maintenance programme in Years each of 1, 11, 21 etc.

7.3.4.3 Labour for cutting - number required and cost

7.3.4.3.1 Cost per unit of labour

In the present example the daily rate for a manual labourer is taken to be KSh.33.42 (National Irrigation Board, Mwea 1994).

7.3.4.3.2 Number of units of labour required

The number of labour days required to maintain primary and secondary canals at Mwea ISS depends upon the productivity of manual cutting and is calculated as follows:

Number of labour days required to manually cut 90,000m of main and branch canals	1,800 days
Number of labour days required to manually cut 90,000m of main and branch canals twice a year	1,800 x 2 = 3,600 days

7.3.4.3.3 Annual input cost of labour for this maintenance programme

The annual input cost of labour is a function of the total number of labour days and the daily labour rate. It is calculated as follows:

Annual input cost of 3,600 labour days	KSh.33.42 x 3,600 = KSh.120,312

7.3.5 Life-cycle costs of the maintenance programme

The annual costs associated with the specified maintenance programme for primary and secondary canals at Mwea ISS are laid out in Table 7.6. They are based on the inputs derived in the previous section but exclude overheads. A 15-year planning period is used in this example, as explained in Section 7.4.1.

Table 7.6 Annual input costs for the specified maintenance programme

Year	Inputs	Input costs per unit (KSh)	Number of units	Annual input cost (KSh)	Total annual input cost (KSh)
1	Capital cost of excavator	9,000,000.00	5	11,250,000.00	
	Recurrent costs of excavator	701,108.63	5	876,385.79	
	Capital cost of hand-tool	120.00	60	7200.00	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			12,253, 897.79
2	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
3	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
4	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
5	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
6	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
7	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
8	Capital cost of excavator	9,000,000.00	5	11,250,000.00	
	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			12,246,697.79

9	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
10	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads				996,697.79
11	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Capital cost of hand-tool	120.00	60	7,200.00	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			1,003,897.79
12	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
13	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
14	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			996,697.79
15	Capital cost of excavator	9,000,000.00	5	11,250,000.00	
	Recurrent cost of excavator	701,108.63	5	876,385.79	
	Cost of labour	33.42	3,600	120,312.00	
	Overheads	excluded			12,246,697.79

Note: costs at 1994 constant prices, based on Mwea ISS, Kenya.

7.4 Calculation of the present value of costs

7.4.1 Rationale and procedure

The annual costs over the planning period may be converted to an equivalent present value, by applying discount factors or weights to each year's costs, based on discounted cash flow techniques to take account of the effect of time (see Box 7.1). The present value can also be expressed as an annualised cost, which represents the amount which must be recovered each year to cover the costs of the maintenance programme over the long-term. This may be recovered from charges levied, grants from government or profits from other activities.

Box 7.1 The Economic Effect of Time.

Selecting an arbitrary interest rate (say 10 %) and examining the present value of $1 at future points in time shows the present value to decline. Thus the present value of a nominal $1 received (benefit) or incurred (cost) three years from now is only 75 cents and the same nominal dollar 20 years from now has a present value of less than 15 cents. This decline in value is attributable to the opportunity cost or sacrifice in waiting for future receipts or incurring future expenditures.

With respect to waiting for returns on investment (revenues), the more distant is the time of receipt in the future, the bigger is the opportunity cost (sacrifice). Late receipt means interest earning opportunities are foregone. At 10% interest rate $100 received now would have grown at compound interest to $133.1 in three years time (see Appendix).

Therefore, having to wait for receipt of $100 for three years involves the sacrifice of $33.1 of accumulated interest. Hence each $1 received three years from now has a today's value (i.e. present value) of only 100 / 133.1 = 0.751 or about 75 cents. This means that $1's worth of revenue received three years from now should be recorded in the investment appraisal as 75 cents to reflect the economic cost of waiting.

Similarly with respect to costs, the delay or postponement of costs into the more distant future reduces their burden and hence the present value of each nominal dollar expended. Thus, delaying the payment of $100 worth of costs for three years reduces the burden in today's value to $75.

This consideration does not mean that delaying costs is necessarily a good strategy. Delays may imperil the performance of the irrigation system leading to large decreases in benefits and storing up major costs to be incurred later. Future remedial payments may well outweigh the savings from a strategy of delay.

Formally, the procedure is summarised as

$$\textit{present value} = \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \frac{C_4}{(1+r)^4} \; \ldots\ldots + \frac{C_{15}}{(1+r)^{15}}$$

where C_1 is the capital cost attributable to this function expended in Year 1.

$C_2 \ldots C_{15}$ are the annual recurrent costs (i.e. labour and inputs) tied to specific years as indicated by the numerical subscripts.

$1+r \ldots (1+r)^{15}$ are the appropriate discount rates given the assumed interest rates for Years 1-15.

The procedure is as follows:

- determine the stream of input costs for specific years (Table 7.6) over the planning period.
- apply the appropriate discount factors to bring the stream of annual costs to their present values.

- sum the annual discounted costs to yield the present value of costs for the programme.

Table 7.7 shows the calculation of the present value of the selected maintenance programme using a discount rate of 20%, and the annualised cost per kilometre. The present value of costs is KSh.17.4 million. For each kilometre cleared in each year of the investment cycle the sponsoring institution needs to recover KSh.41,352.60.

The 15 year planning period is necessarily arbitrary, but was chosen to allow the inclusion of occasional but substantial expenditures associated with particular maintenance programmes. Prolonging the period beyond 15 years was rejected because discount factors become so small that results are not seriously affected and uncertainties increase with planning period length.

The values of the present value and annualised cost depend on the selected discount rate used (see Box 7.2). The discount rate is selected to reflect the interest rate that the agency has to pay on borrowed funds, or the interest rate that it might have earned on invested funds. Its purpose is to reflect the opportunity cost of capital used in the maintenance programme. Choice of a high numerical value for the discount rate applies a more stringent or exacting financial test to the clearance strategy implying a high opportunity cost of funds used. Conversely, a low value of discount rate implies a low opportunity cost of funds.

With everything else equal, a higher discount rate reduces the present value of the costs of a maintenance programme (as described in Box 7.2). The sensitivity of the present value of costs of a programme to the choice of discount rate is a prudent test, so the present value is usually calculated for a range of discount rates.

The numerical values of the weights for values of years hence and alternative values of discount rate are presented in Appendix 2 for use in these calculations.

Table 7.7 Calculation of the present value and annualised costs for the specified maintenance programme

Year	Inputs	Input costs per unit	Number of units	Annual input cost	Annual total input cost	Discount factor 20%	Present value of costs
1	Capital cost of excavator	9,000,000.00	5	11,250,000.00			
	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Capital cost of hand tool (panga)	120.00	60	7,200.00			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	12,253,897.79	0.833	10,207,496.86
2	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.694	691,708.26
3	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.579	577,088.02
4	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.482	480,408.33

5	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.402	400,672.51
6	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.335	333,893.76
7	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.279	278,078.68
8	Capital cost of excavator	9,000,000.00	5	11,250,000.00			
	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	12,246,697.79	0.233	2,853,480.58
9	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.194	193,359.37
10	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.162	161,465.04
11	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Capital cost of hand-tool (panga)	120.00	60	7,200.00			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	1,003,897.79	0.135	135,526.20
12	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.112	111,630.15
13	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.093	92,692.89
14	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	996,697.79	0.078	77,742.43
15	Capital cost of excavator	9,000,000.00	5	11,250,000.00			
	Annual recurrent costs of excavator	701,108.63	5	876,385.79			
	Annual cost of labour for cutting	33.42	3,600	120,312.00			
	Overheads			excluded	12,246,697.79	0.065	796,035.36
	Sum of present value of costs						**17,391,278.45**
	Sum of present value of costs per km						**193,236.43**
	Annualised cost per km						**41,352.60**

The estimated seven-year life of a hydraulic excavator results in the purchase of new excavators in Year 15, the final year of the planning period. However the table shows that this has little impact on the present value when a 20% discount rate is used. This supports the choice of a 15-year planning period - even large expenditures this far into the future have little impact on the present value.

Box 7.2 The Economic Effect of the Size of Interest Rate.

Examination of the present value of $1 table shows that as the interest rate (discount rate) increases so the present value of $1 declines indicating that at higher rates of interest the opportunity cost of waiting increases. More interest is sacrificed and hence nominal dollars are worth less.

Selecting an arbitrary year in the future (say, Year 8) shows that the present value of $1 declines reflecting the large penalty attached to waiting as the interest rate increases.

If interest rates were very low over the planning period the economic cost of waiting would be low as little interest earning potential is lost. At very high interest rates the sacrifice of waiting is accordingly high. Likewise with costs, as interest rates increase the present value of each dollar's worth of costs declines (i.e. the burden becomes less). This reflects that with a higher interest rate over a given period each dollar will grow at compound interest to a higher figure thereby reducing the burden of each nominal dollar of cost.

7.4.2 Inflation and Investment Appraisal

It is to be noted that the rationale of discounting to present value lies in the need to incorporate the time value of money into decision-making. It is not a device for including inflation (i.e. changes in the general price level) into the calculations. Even in a world of zero inflation (i.e. constant general price level) the considerations outlined above would still hold. This is not to say that inflation is not important in the management of irrigation systems but it is not important in the context of present value investment appraisals designed to choose between alternatives.

The significance behind the assertion is that in present value calculations there is no need to incorporate forecasts of future general inflation into the cost estimates. All costs, and benefits where relevant, should be estimated at constant (i.e. today's) prices.

7.4.3 Depreciation

Provision for depreciation is not made in present value investment appraisals. The word depreciation is subject to a variety of interpretations. The most important concept of depreciation deals with the process of allocating the investment cost of fixed assets to the production expenses of operations by accounting periods.

The present value investment appraisal technique attaches the capital cost of fixed assets (say, excavators) to the year in which they are actually incurred. To include apportionment of capital costs in the calculation and provision for depreciation would thus involve double counting, that is, inclusion of capital costs twice.