Chapter 26
Equipment Replacement Decisions

Abstract The aim of this chapter is to present the factors involved in decisions relating to the replacement of equipment, and to show how replacement decisions can be analyzed. Various scenarios relating to replacement analysis based on increasing maintenance cost with age presented. The use of spend-limits as a replacement control mechanism is presented and the role of risk analysis in replacement decisions. Factors involved in the replacement of *linear assets* such as pipelines, power lines, roads, and rail lines are discussed and component replacement policies. *Outcomes* After reading this chapter you will be aware of the factors which influence equipment replacement decisions. You will know that financial analysis of replacement policy is based on comparing the estimated future costs of the existing equipment with that of a challenger. You will know about spend-limits and their role in the setting of replacement policies and how risk might be taken into account. You will also be aware of factors involved in component replacement decisions.

26.1 Replacement Planning

H.M. Barker in his book "Camels and the Outback" reports that in 1923 he was carting material from Nullagine to Marble bar in Western Australia when his camel wagon, for which the 90 km journey took 3 days, was overtaken by a motor lorry—the first one in the region. He thought that the lorry was a novelty that would never seriously compete with his camels, but by the time he got to Marble Bar the lorry had passed him three more times, and the mine manager had sent word that his wagon would not be required any more.

Organizations need a systematic approach to the development of replacement plans. Flexibility must be retained as priorities may change, but a backlog of replacements should not build up to a point where losses or serious risks are occurring. The magnitude of such losses or risks is often a more important factor than the achievement of precise cost optimality in replacement planning.

Those who wish to win friends and influence people never bring bad news, as the reaction of senior people is often to shoot the messenger. Replacing existing equipment is rarely the glamour side of business management and this creates a dilemma for asset managers whose job involves replacement planning.

The best approach is to have a rolling plan in which all forward replacement requirements are indicated well in advance, the costs are built into the capital budget, and the acquisition lead times are allowed for. The asset manager can then become an occasional bringer of good news if some items turn out to be in better condition than originally anticipated as their forecast replacement date approaches. Risk assessments should be included, so as to provide senior management with information on relative priorities. However, it is important to avoid crying wolf or being too smart after event. Putting forward reasoned proposals with an associated risk assessment will produce the best results.

Lack of sufficient focus on equipment condition within an organization can lead to a procrastination driven tragedy. The asset manager requests finance for equipment replacement but is asked to prove that it is essential. This is hard to substantiate, the money is not forthcoming, and eventually a significant failure occurs. The asset manager is then criticized for "not warning" senior management about the problem. A more extreme version is the asset death spiral mentioned in an early chapter. In that scenario, maintenance and replacement budgets and technical infrastructure are reduced creating short-term savings. Routine maintenance becomes minimal or nonexistent. Eventually a catastrophe occurs.

26.2 Reasons for Equipment Replacement

As equipment ages there are many reasons why we eventually need to replace it. Key factors influencing replacement decisions include the following; in many cases more than one factor will come into play at the same time.

Operational reasons

- Reduced performance through degradation or relative to newer equipment types
- Reduced availability
- Reduced reliability

Technical reasons

- Equipment not repairable at all
- Equipment not logistically supportable, e.g., spares not available, repair facilities not available
- Increased risk of failure, long term deterioration e.g., corrosion, fatigue, insulation deterioration, with associated risk-costs

Commercial reasons

- Operationally obsolete
- Capacity needs have changed, increased or decreased
- Operating value low compared with new
- Operating costs high compared with new
- Maintenance costs high compared with new
- Item requires repair, the cost of which is unlikely to be recovered.

Regulatory reasons

- Safety or health issues
- Environmental issues
- Government regulator's rules favor replacement because they are based on book value which is now low or zero
- Technical regulations changed, e.g., increased fuel efficiency mandated.

Figure 26.1 shows a flowchart covering the logic of replacement decisions. The box at the top left summarizes physical or operational reasons for equipment replacement. Financial issues may include economic life, the spend-limit considered in a later section, and risk-cost, that is the probability of incurring an excessive cost as a result of a risk eventuating. In some cases it may be possible to redeploy or refurbish equipment and these possibilities are covered in the flow-chart. The flowchart was developed for items with a focus on service provision and cost minimization, rather than on profit generation. In a profit focused case, net operating value would be an issue, rather than cost alone.
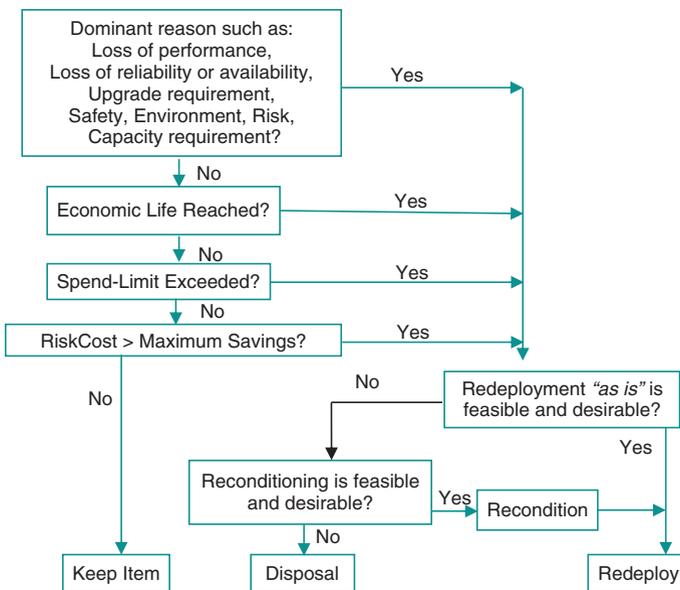

Fig. 26.1 Replacement analysis flowchart

26.3 Technical Assessment

An awareness of criticality and the identification of high risk items is important in the overview of technical condition and replacement analysis. The condition of the existing equipment, particularly in regard to things that deteriorate with age and are not readily remedied, should be monitored. Condition monitoring techniques should be deployed to obtain indications of equipment state, and this can give an advance indication of when replacement will be required. Factors to be considered include corrosion, insulation deterioration, embrittlement of plastics, moisture penetration, fatigue, erosion, wood rot, surface degradation, cracking, and movement of structures.

   The performance of existing equipment should be monitored in regard to operational efficiency, reliability, availability, and maintainability, and the results assessed in relation to the needs of the organization. In some cases, older equipment can be deployed to less critical tasks or to standby roles rather than being discarded. Degradation in performance or in regard to risk of failure often forms the basis for equipment replacement.

26.4 Data Analysis

Replacement decisions are generally based on assessment of changes in performance, reliability, and risk as equipment ages. Data relating to these factors are often present in the form of operating and maintenance records, but in order to use this data, suitable reports need to be generated from it. These should highlight changes in operating performance, failure rate, and maintenance costs, forming the basis for sound decisions for replacement of equipment. Experience and gut feel can also play a role, but data analysis is the best approach.

26.5 Cost Analysis for Replacement

Whatever the reason for replacement of equipment, a supporting financial analysis will normally be required, and we now consider the types of analysis needed.

26.5.1 Like-with-Like Replacement

In the chapters on life cycle costing and economic life we considered life cycle-based cost analysis, and the determination of an equivalent annual cost (EAC) over the life cycle. In the case of like-with-like replacement, the economic life determined from that analysis provides the guideline for our replacement decision.

   An important fact to recognize is the acquisition cost of a new item is always likely to be greater than the current year cost of keeping an old item; but to

minimize long-run costs we need to replace an old item when its current year costs exceed the *annualized* life cycle cost (EAC) of the *new* item, not the acquisition cost. This principle underlies all replacement cost analysis.

26.5.2 Equivalent Annual Cost of the Challenger

In practice, we are likely to find that we are making decisions about replacing equipment of an earlier type with equipment of a newer type. This may give rise to a need to replace for broader reasons than direct equipment cost, and these reasons have already been discussed. We now consider the case where the "competition" between existing equipment and new equipment is based on cost grounds.

We can refer to the existing equipment as the old equipment and to the potential replacement as the new equipment. Another form of nomenclature is to refer to the potential new equipment as the "challenger" and the existing equipment as the "defender".

Consider a situation where we are considering buying a new car to replace an existing one. The new car is the challenger and the old car is the defender. The price of the challenger will be a factor in our decision, since if prices have tended lower, we will be likely to make the changeover sooner than if they have tended higher. In the current year, the acquisition price of the challenger will be almost sure to exceed the maintenance cost of the defender in that year, and if we based our comparison solely on the immediate year's costs we might postpone our decision for a very long time. The correct approach is to consider the EAC of the challenger over its lifetime and compare this with the EAC of the defender over its *estimated remaining life*. This analysis requires us to make an estimate of the EAC of the challenger, so that life cycle costing analysis is required for the new equipment. Previous expenditure on the existing equipment is a sunk cost and not relevant to our decision. Indirectly though, previous expenditure may be a factor influencing the current condition of the existing equipment, which is a consideration.

26.5.3 Steadily Increasing Cost Case

If the cost of the old item increases steadily year by year, the decision to replace is based on comparing the cost of keeping the old item for one more year, as against the annualized cost of the new, or challenger, item. The annualized cost of the new item is the EAC, as estimated by life cycle costing.

The cost of the old item includes the maintenance cost, any decline in resale value, and costs associated with declining performance relative to a new item. For example, if the old item incurs relatively high down time we should include an estimate of the cost involved, compared with the corresponding lifetime average down time per year of the challenger.

Figure 26.2 illustrates the steadily increasing cost case. The "X" symbols represent the annual maintenance costs of the old item. The EAC of the new item is

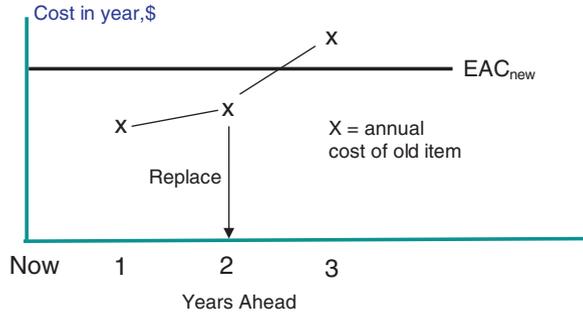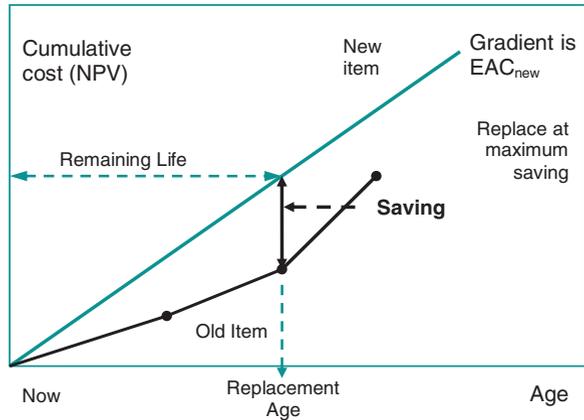**Fig. 26.2** Replacement analysis—steadily increasing costs

Fig. 26.3 Cumulative cost comparison

referred to as EACnew. The old item should be replaced at the end of the second year from now, as in the third year ahead (and subsequently) the annual costs of the old item will exceed EACnew.

26.5.4 Savings

Another way of representing the cost comparison is by means of a cumulative plot as shown in Fig. 26.3. The cumulative cost of the old item is the lower solid line. The upper solid line has gradient equal to the EAC of the new or challenger item. In the cumulative plot the gap between the "new" and "old" lines represents the savings accumulated by continuing to use the old item. In Fig. 26.3 the optimum replacement age is when the difference between the new and old lines is a maximum. The extent of the savings can be considered when assessing risk or other intangible aspects of the replacement option. Thus, if the total savings are quite small in relation to a possible risk, we may decide to replace before the theoretical minimum cost point.

As time goes by the origin of the graph shifts to the new "Now" and the potential savings from keeping the old item decrease, and ultimately disappear.
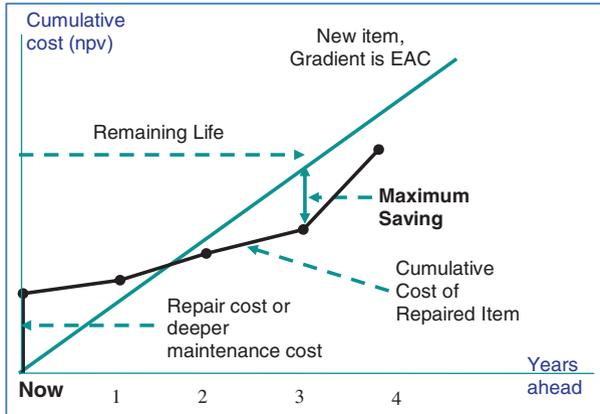
Fig. 26.4   Variable cost case

26.5.5 Unevenly Changing Cost Case

The cumulative plot analysis also covers the case where the cost of the old item does not increase steadily, but can vary, for example due to deeper maintenance taking place on a cyclic basis. In this case, the cost in the deeper maintenance year may be above the EAC of the new item, but then falls in the rest of the maintenance cycle. The point of maximum savings on the cumulative plot gives the optimal replacement age. The same analysis applies where a one-off significant repair is required now; or where a refurbishment that will subsequently lead to lower costs is being considered.

Figure 26.4 shows a case where an equipment requires a major repair now, and a forecast has been made of subsequent costs following repair. No costs are expected in year 1. In years 2, 3, and 4 costs are low initially but then gradually increase. In year 2, the cumulative cost curve for the old item (repaired item) falls below the cumulative cost line for the challenger (new) item yielding savings. The optimal remaining life occurs when the saving is a maximum. As shown, this occurs at year 3.

If the cumulative cost line of the repaired item does not fall below the new item line, then it is not worthwhile to carry out the major repair. This analysis can be used to indicate whether a proposed repair or refurbishment is financially worth-while. The magnitude of the potential savings can be used as a judgment factor in deciding whether to undertake the repair, and in risk analysis.

26.6 Spend-Limits

We can sometimes find that excessive amounts are spent on uneconomic repairs unless rules preventing this are put in place. Such rules are known as spend-limit rules or repair-limit rules. A spend-limit is a limit on the amount which it

is permitted to spend on repair or refurbishment of an existing item. The value of a spend-limit will depend on the type of item, its age, and the replacement options and costs. The operation of a spend-limit system depends on the availability of replacement items. As such it is typically applicable to items of intermediate value, such as vehicles, radio sets, common user motors, or pumps, where there is access to a replacement pool.

Logically, no more should be spent on the repair of an item than the item is worth. As a quick guide, the book value of an item acts as an upper limit on how much to spend on repair at any point. If the book value does not accurately reflect the value of the item to the business, the spend-limit should be the maximum savings from retaining the old equipment, as shown in Figs. 26.3 or 26.4. An item that requires a repair whose cost exceeds its spend-limit should be replaced.

The "spend-limit" concept can be illustrated by the following common application. If a vehicle incurs accident damage which exceeds its second-hand value, then the company that insures the vehicle will normally specify that the vehicle is written off and is not repaired. The second-hand value acts as a limit on the amount that is worthwhile spending on the repair. This reflects a basic principle that no more should be spent on the repair of an item than the item is worth after repair. The value after repair is a "spend-limit" for an item.

26.6.1 Spend-Limit Example

A bus company has a number of old buses which are used only on days of high demand. Repair/replacement decisions are controlled by spend-limits. The spend-limit for old buses is set to a level which allows buses with no problems or requiring very minor repairs to be retained, but repairs involving major assembly replacement or major bodywork are ruled out.

26.7 Risk with Ageing Equipment

Equipment replacement decisions often need to take account of risk. Average cost per unit time will decrease initially as the acquisition cost is amortized, as shown in Fig. 26.5. But then, rather than tending slowly upwards, there may be a sudden jump in costs due to a major failure. This type of behavior occurs with items whose maintenance costs are low relative to their capital cost, but which can

Fig. 26.5 Long life equipment with risk
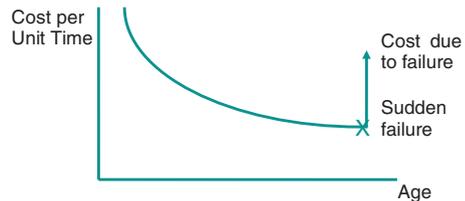
experience catastrophic failure. Power transformers provide an example. In such cases it is essential to take account of risk as equipment ages.

Senior management should be involved in the assessment of the risks and consequences arising in any such situation, as their estimate is likely to be the best available, and their ability to make a sound judgmental decision in terms of the business as a whole may save needless and possibly inaccurate analysis.

Where suitable data is available we can estimate levels of risk. For example, an electricity transmission company with complete data on all failure and maintenance history of its transformers estimated the probability of major failure related to age and to other measures of transformer utilization and condition. From this it was able to draw up guidelines for preventive replacement polices which kept the probability of major failure to low levels. It is generally not possible to eliminate all risk. Where less data is available we may need to rely on technical judgment to guide our replacement policies.

26.7.1 Risk-Cost

Risk-cost is the probability that an adverse event occurs multiplied by the cost if it does. Although risk-cost can be a useful guide to our thinking, the product of a very low probability multiplied by a very high cost does not always result in a meaningful value when related to conventional financial analysis.

For example, the probability of an old transformer failing in the coming year was estimated at 1 % and the cost of this event at $5,000,000. The product of these numbers gives a risk-cost of $50,000. $50,000 is too small an amount to warrant replacement, but in practice the senior management made the decision to replace based on the potential impact of a major failure at the overall business and political level.

26.8 Linear Assets[1,2]

A "linear asset" is an asset which is physically long, consists of a series of individually inexpensive sections or components, but delivers a valuable service, with high costs if the service is interrupted. Examples are water mains, oil and gas pipelines, roads, railway track, and electricity power lines. The critical factor is service availability. Replacement problems associated with linear assets have particular characteristics which are discussed here.

---

[1] The Replacement Decision For Linear Assets, P. Buckland and N. Hastings, (International Conference of Maintenance Societies—ICOMS 2001—Melbourne, Australia—May 2001).

[2] Buckland P—"Risk Based Economic Life Cycle Management of Infrastructure Assets and its Regulatory Implications"—Proc. International Conference of Maintenance Societies ICOMS 2000—Wollongong—May 2000.

26.8.1 Cost Structure

Linear assets typically have the following features.

- There is a significant initial capital outlay.
- There are little or no operating costs.
- Routine maintenance costs are low.
- For a long time there are few failures.
- There are minimal administrative costs.
- Failures cause high costs to users.
- Failures are repaired promptly, usually as an urgent job.
- Short lengths of the asset can be repaired quickly and relatively cheaply.
- Eventually the asset condition deteriorates significantly.
- Eventually there are significant risk costs.
- Repeated failures are unacceptable and eventually a major refurbishment is needed.
- The extent of and timing of refurbishment are hard to decide.
- Disposal cost is low.

The key characteristic is the eventual occurrence of failures which have high costs to users. Individual failures can be fixed and the cost of repair is relatively small, but repeated failures are unacceptable. Guidelines for making the decision to refurbish some or all of the asset can be:

- the failure rate, such as failures per kilometer per year,
- an availability figure which takes account of failure rate and time to repair (outage time),
- a failure severity measure,
- a cost-based measure which assigns costs to the outages. In this case replacement can occur when marginal cost exceeds the estimated EAC of the replacement,
- a risk-cost based measure for items which can be catastrophic if they fail, such as trunk water mains.

26.8.2 High Consequence Assets

High consequence assets, such as trunk water mains, are assets that we do not want to fail at all. Where risk comprises rare but very high consequence events, such an event may not have occurred in the past and it will not be reflected in historical records. For trunk mains, we would expect to be making the replacement decision without having a failure history.

In such cases, we are dependent on predictive assessment which will indicate at what stage in the degradation of the asset we will make a replacement. This is primarily a technical assessment and may be based on a combination of observed condition and technical information based on such factors as erosion or corrosion rates, fatigue life, or wear rates. It is important that adequate steps are taken to monitor the risks associated with high consequence assets and to act in time to

avoid failure. High consequence assets feature an economic life shorter than their physical life.

The risk analysis involves the less tangible aspects of failure such as social impact and image damage.

26.8.3 Low Consequence, Long Life Asset Replacement

Consider an asset type with low failure consequence, which has a high acquisition cost, followed by a long period with little or no expense. This is typical of many linear assets. Some failures are acceptable and the rate may be low when the asset is new, so initially we may operate on a run-to-failure basis. Later, the failure rate rises as the assets age, and will gradually become unacceptable. It is important to monitor the failure rate so that we become aware of when to consider the introduction of a replacement or refurbishment policy which goes beyond minimal repairs.

Thus in this case we switch from an initial repair-only-on—failure policy to a refurbishment policy once the failure rate becomes significant. The increase in failure rate is not necessarily uniform across the population. For example, in an electricity transmission network, lines close to the coast will be subject to faster rates of corrosion than lines inland. This is due to salt laden air. Also, lines in exposed open terrain will be subject to wind-induced vibration to a greater extent than lines in sheltered locations, leading to possible fatigue failures.

26.9 What Length of Asset Should Be Replaced?

Another issue that arises with linear assets is deciding how much of the asset, should be replaced in any one replacement episode.

For the purpose of maintenance or replacement of linear assets it is convenient to consider them as being made up of discrete sections. This may be driven by physical attributes, e.g., the span between transmission line towers or sewer access shafts, or by the limitations of data capture systems in providing detail of asset performance. It may also be influenced by failure patterns or environmental conditions.

What do we replace and what do we leave? Do we replace only individual sections with a failure history? What do we do about sections with no failure history but which are located adjacent to those being replaced?

26.9.1 Cost Structure of Replacement

With most linear assets there are economies of scale such that it is cheaper per meter to replace longer lengths. This affects the decision as to how much of a degraded asset should be replaced. Figure 26.6 shows the variation of fixed costs
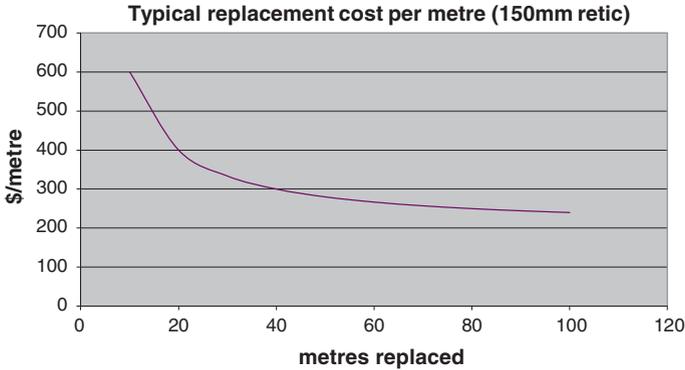
Fig. 26.6   Economy of scale in pipe replacement

with price per meter and total length laid in a single episode for 150 mm water mains. It is evident from Fig. 26.6 that the EAC of a section of a linear asset will be dependent on the magnitude of the project by which it is acquired.

The decision as to how much of an asset to replace in any one episode will depend on a number of factors. These include:

- the physical practicalities of replacement,
- the relationship between the site establishment fixed costs,
- the length-related variable costs of replacement,
- the condition of the asset under consideration, and
- site-specific considerations.

Fixed costs include:

- Site establishment;
- Notification to customers of a planned replacement;
- Social cost of disruptive event (outrage, loss of amenity);
- Administration (contract preparation, tendering, payment etc.).

Variable costs include:

- Labor
- Plant
- Material
- Administration (contract admin and supervision)
- Social cost of extended disruption (traffic disruption, commercial disruption, residential access problems, noise, unsightliness, etc.). This is a cost that displays an increasing rate with time.

The cost structure of the replacement process is such that it imposes disincentives for too small a replacement and for too big a replacement. We may therefore, surmise that with all benefits and costs considered there will be a site-specific "preferred" replacement episode.

Fig. 26.7 Condition of linear asset
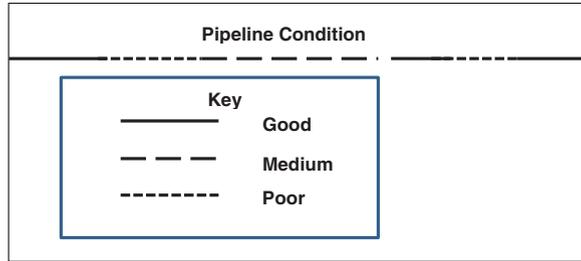
26.9.2 Contiguous Replacement

Consider the linear asset shown as "Pipeline Condition" in Fig. 26.7. This has sections featuring good, medium, and poor condition distributed along its length.

A number of options can be considered, such as:

- to replace only the poor sections one at a time in separate jobs,
- replace only the poor sections in one job,
- to replace the poor and adjacent medium sections in separate jobs,
- to replace a contiguous length including both poor sections and the sections in between in a single job.

Decisions must be made between these options and there is no simple formula. The techniques already outlined can be used to evaluate particular cases.

26.9.3 Linear Assets Conclusion

Linear assets have specific characteristics which complicate the replacement policy. Degradation can creep in gradually and may have serious consequences. The factors outlined in this section form a basis for informed decisions on the replacement of linear assets. The actual decision in any particular case will depend on the balance of condition, cost, and disruption factors, and will need to be made on a case-by-case basis.

26.10 Component Replacement[3]

Components may be replaced on the following bases:

- On condition

---

[3] N.A.J. Hastings, Component Replacement Analysis with Incomplete Failure Data, in *Case Studies in Reliabiliity and Maintenance*, W. R. Blischke and D.N.P. Murthy eds., Wiley, New York, 2003.

- On age or service life
- On failure

It is also possible to use these policies in combination.

26.10.1 Condition-Based Replacement

A condition-based replacement is a replacement which is carried out when a component is still working satisfactorily, but inspection or monitoring shows that it has degraded and can be expected to fail in the near future. Condition-based replacement is a sound policy if it is technically and economically feasible to apply an effective condition monitoring policy to the component.

Otherwise, the choice is between an age-based policy or a replace-only-on-failure policy.

26.10.2 Failure Replacement and Run-to-Failure

A failure replacement is a replacement that occurs following the failure of a component in service. Whatever the policy, replacement will be required if the component actually fails. If no other policy is adopted, the policy will be to replace only on failure, also known as run-to-failure. This may not be acceptable because of the cost of failure and possible safety or environmental consequences.

An example, where a run-to-failure policy is commonly applied, is with domestic lighting. The consequences of an individual light failing are not severe and there is no suitable condition monitoring system. Redundant systems can generally be suited to a run-to-failure policy, with the switch to a standby or parallel system allowing time for replacement to occur.

26.10.3 Age-Based or Service-Based Replacement

An age-based or service-based replacement is a replacement which is carried out when a component is still working satisfactorily, but we consider it advisable to replace it on a basis of age or in terms of service life, such as flying-hours.

Data on component ages must be kept for this policy to be applied. Age-based replacement should not be applied where the failure rate is decreasing or constant, as the new item will be no more reliable than the old. We therefore need to carry out analysis or make a technical judgement as to the age at which the failure rate

will increase. However, it may be necessary at times to make age-based replacement in anticipation of a rising failure rate before another replacement opportunity arises. Age-based rules commonly apply to safety-critical components such as pressure safety valves and aero-engines. Methods for determining when the failure rate starts to increase are discussed in Chap. 21, Sect. 21.7.4.1 under the headings of statistical analysis and age exploration.

26.11 Exercises

26.11.1 Vehicle Replacement Exercise

A vehicle currently has a resale value of $25,000 and is estimated to have a resale value of $18,000 in a year's time. The maintenance cost of the vehicle for the coming year is $3,500, assumed to be incurred at the end of year.

The life cycle EAC of a new vehicle is estimated at $10,000 per year. Should the old vehicle be replaced now?

a. assuming zero interest; and
b. assuming interest at 10 % p.a.

26.11.2 Transformer Replacement Exercise

An electricity transmission company has a transformer which is currently 40-years old. The operating and maintenance costs for this item for the next 4 years have been assessed as follows. Assume that these costs are incurred at the END of the respective years. Assume that the old transformer will not be kept for more than 4 years.

Year	1	2	3	4
Cost	14,250	14,200	24,000	45,450

A new transformer of modern design can be purchased for $300,000. The new transformer can be assumed to have a 40-year life. The cost of capital is 8 % and the 40-year annuity factor at 8 % per annum is 11.9246. The annual operating and maintenance cost for the new transformer is estimated at an EAC of $2,700 per annum.

(a) On the basis of this data, at what age should the old transformer be replaced? Show your working.
(b) If the old transformer needed a repair, costing $30,000, should this repair be carried out or should the old transformer be replaced now? Assume that the old transformer has no net disposal value. Assume that this repair will not affect the future costs shown in the table. Show your working.

Transformer replacement solution template:

1. Calculate new transformer EAC

Capital cost	
Life in years	
Annuity factor	
Capital cost EAC	
Maintenance cost EAC	
Total EAC	

2. Calculate new transformer cumulative NPV

1	Year	1	2	3	4
2	New trans EAC				
3	Discount factor	0.9259	0.8573	0.7938	0.7350
4	New trans NPV				
5	New trans cumul NPV				

3. Calculate old transformer cumulative maintenance cost, rows 6–8
4. Calculate savings from keeping old transformer, row 9

6	Old trans maint	14,250	14,200	24,000	45,450
7	Old trans maint NPV				
8	Old trans cumul maint NPV				
9	Savings row 5–row 8				

Answer

(a) Replacement Age =
(b) Repair Yes/No.

26.11.3 Spend-Limit Exercise

A company has a machine that requires a reconditioned engine at a cost of $25,000, but is otherwise satisfactory. We estimate that the machine will last for three more years if it gets the new engine, and that its expected maintenance cost over this period will be $3,000 per year. The Life Cycle Equivalent Annual Cost (EAC) of a new machine is $10,000 per year.

Should we replace the engine or scrap the old machine? Assume zero resale value if the machine is scrapped. Ignore discounting over the 3-year period.
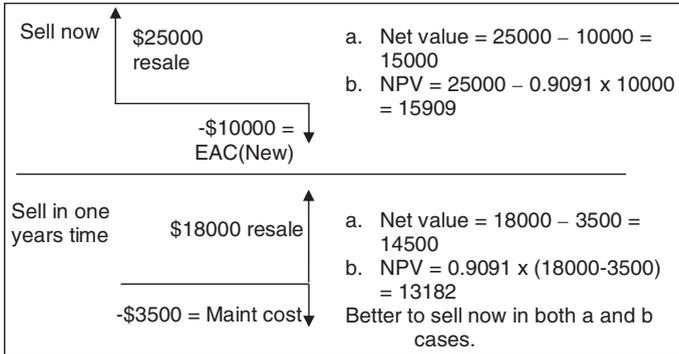
Fig. 26.8   Vehicle replacement options

26.12   Solutions to Exercises

26.12.1   Vehicle Replacement Exercise Solution

It is better to sell now in both the (**a**) and (**b**) cases (Fig. 26.8).

26.12.2   Transformer Replacement Exercise

Calculate new transformer EAC

Capital cost	300,000
Life in years	40
Annuity factor	11.9246
Capital cost EAC	25,158
Maintenance cost EAC	2,700
Total EAC	27,858

Calculate new transformer cumulative NPV

1	Year	1	2	3	4
2	New trans EAC (EOY)	27,858	27,858	27,858	27,858
3	Discount factor	0.9259	0.8573	0.7938	0.7350
4	New trans NPV	25,794	23,882	22,114	20,476
5	New trans cumul NPV	25,754	49,678	71,793	92,269

Calculate old transformer cumulative maintenance cost NPV. Calculate savings from keeping old transformer (row 9)

6	Old trans maint EOY	14,250	14,200	24,000	45,450
7	Old trans maint NPV	13,194	12,174	19,052	33,407
8	Old trans cumul maint NPV	13,194	25,368	44,420	77,827
9	Savings row 5–row 8	12,600	24,310	27,373	14,442

Answer

(a) Replace at age 43 (savings are maximum).
(b) Do not repair as savings < 30,000.

26.12.3 Spend-Limit Exercise

The spend-limit is given by:

$$\text{Spend} - \text{limit} = \text{EAC(new)} * 3 - \text{Annual maintenance cost of old} * 3$$
$$= \$10,000 * 3 - \$3,000 * 3 = \$7,000 * 3 = \$21,000.$$

The maximum that we should be willing to spend on repair is $21,000.
To repair the old machine will cost $25,000.
Hence, it is cheaper to replace the old machine.
Alternative method with the same result:
Cost of old = 3 * 3,000 + 25,000 = $34,000
Cost of new = 3 * 10,000 = $30,000 = cheaper.