

Dependability management —

Part 3-3: Application guide — Life cycle costing

The European Standard EN 60300-3-3:2004 has the status of a
British Standard

ICS 21.020

National foreword

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Part 3-3: Application guide –
Life cycle costing
(IEC 60300-3-3:2004)

Gestion de la sûreté de fonctionnement
Partie 3-3: Guide d'application -
Evaluation du coût de vie
(CEI 60300-3-3:2004)

Zuverlässigkeitsmanagement
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Foreword

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INTRODUCTION

Products today are required to be reliable. They have to perform their functions safely with no undue impact on the environment and be easily maintainable throughout their useful lives. The decision to purchase is not only influenced by the product's initial cost (acquisition cost) but also by the product's expected operating and maintenance cost over its life (ownership cost) and disposal cost. In order to achieve customer satisfaction, the challenge for suppliers is to design products that meet requirements and are reliable and cost competitive by optimizing acquisition, ownership and disposal costs. This optimization process should ideally start at the product's inception and should be expanded to take into account all the costs that will be incurred throughout its lifetime. All decisions made concerning a product's design and manufacture may affect its performance, safety, reliability, maintainability, maintenance support requirements, etc., and ultimately determine its price and ownership and disposal costs.

Life cycle costing is the process of economic analysis to assess the total cost of acquisition, ownership and disposal of a product. This analysis provides important inputs in the decision-making process in the product design, development, use and disposal. Product suppliers can optimize their designs by evaluation of alternatives and by performing trade-off studies. They can evaluate various operating, maintenance and disposal strategies (to assist product users) to optimize life cycle cost (LCC). Life cycle costing can also be effectively applied to evaluate the costs associated with a specific activity, for example, the effects of different maintenance concepts/approaches, to cover a specific part of a product, or to cover only selected phase or phases of a product's life cycle.

Life cycle costing is most effectively applied in the product's early design phase to optimize the basic design approach. However, it should also be updated and used during the subsequent phases of the life cycle to identify areas of significant cost uncertainty and risk.

The necessity for formal application of the life cycle costing process to a product will normally depend on contractual requirements. However, life cycle costing provides a useful input to any design decision-making process. Therefore, it should be integrated with the design process, to the extent feasible, to optimize product characteristics and costs.

DEPENDABILITY MANAGEMENT –

Part 3-3: Application guide – Life cycle costing

1 Scope

This part of IEC 60300 provides a general introduction to the concept of life cycle costing and covers all applications. Although the life cycle costs consist of many contributing elements, this standard particularly highlights the costs associated with dependability of the product.

This standard is intended for general application by both customers (users) and suppliers of products. It explains the purpose and value of life cycle costing and outlines the general approaches involved. It also identifies typical life cycle cost elements to facilitate project and programme planning.

General guidance is provided for conducting a life cycle cost analysis, including life cycle cost model development. Illustrative examples are provided to explain the concepts.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-191:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

IEC 60300-3-12, *Dependability management – Part 3-12: Application guide – Integrated logistic support*

IEC 61703, *Mathematical expressions for reliability, maintainability and maintenance support terms*

IEC 62198, *Project risk management – Application guidelines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-191 and IEC 61703, together with the following definitions, apply.

3.1

life cycle

time interval between a product's conception and its disposal

3.2

life cycle costing

process of economic analysis to assess the life cycle cost of a product over its life cycle or a portion thereof

3.3

life cycle cost

LCC

cumulative cost of a product over its life cycle

3.4

base date

fixed point in time set as the common cost reference

4 Life cycle costing

4.1 Objectives of life cycle costing

Life cycle costing is the process of economic analysis to assess the total cost of acquisition, ownership and disposal of a product. It can be applied to the whole life cycle of a product or to parts or combinations of different life cycle phases.

The primary objective of life cycle costing is to provide input to decision making in any or all phases of a product's life cycle.

An important objective in the preparation of LCC models is to identify costs that may have a major impact on the LCC or may be of special interest for that specific application. Equally important is to identify costs that may only influence the LCC to a very small extent.

The more common types of decisions to which the life cycle costing process provides input include, for example:

- evaluation and comparison of alternative design approaches and disposal options technologies;
- assessment of economic viability of projects/products;
- identification of cost contributors and cost effective improvements;
- evaluation and comparison of alternative strategies for product use, operation, test, inspection, maintenance, etc.;
- evaluation and comparison of different approaches for replacement, rehabilitation/life extension or retirement of ageing facilities;
- allocation of available funds among the competing priorities for product development/improvement;
- assessment of product assurance criteria through verification tests and its trade-off;
- long-term financial planning.

Life cycle costing can be used to provide input to integrated logistic support analysis. See IEC 60300-3-12 for detailed information on integrated logistic support analysis.

4.2 Product life cycle phases and LCC

Fundamental to the concept of life cycle costing is a basic understanding of a product life cycle and the activities that are performed during these phases. Also essential is an understanding of the relationship of these activities to the product performance, safety, reliability, maintainability and other characteristics contributing to life cycle costs.

There are six major life cycle phases of a product as follows:

- a) concept and definition;
- b) design and development;
- c) manufacturing;

- d) installation;
- e) operation and maintenance;
- f) disposal.

The appropriate life cycle phases, or parts or combinations of these phases, should be selected to suit the special needs of each specific analysis. In a general way, the total costs incurred during the above phases can also be divided into acquisition cost, ownership cost and disposal cost.

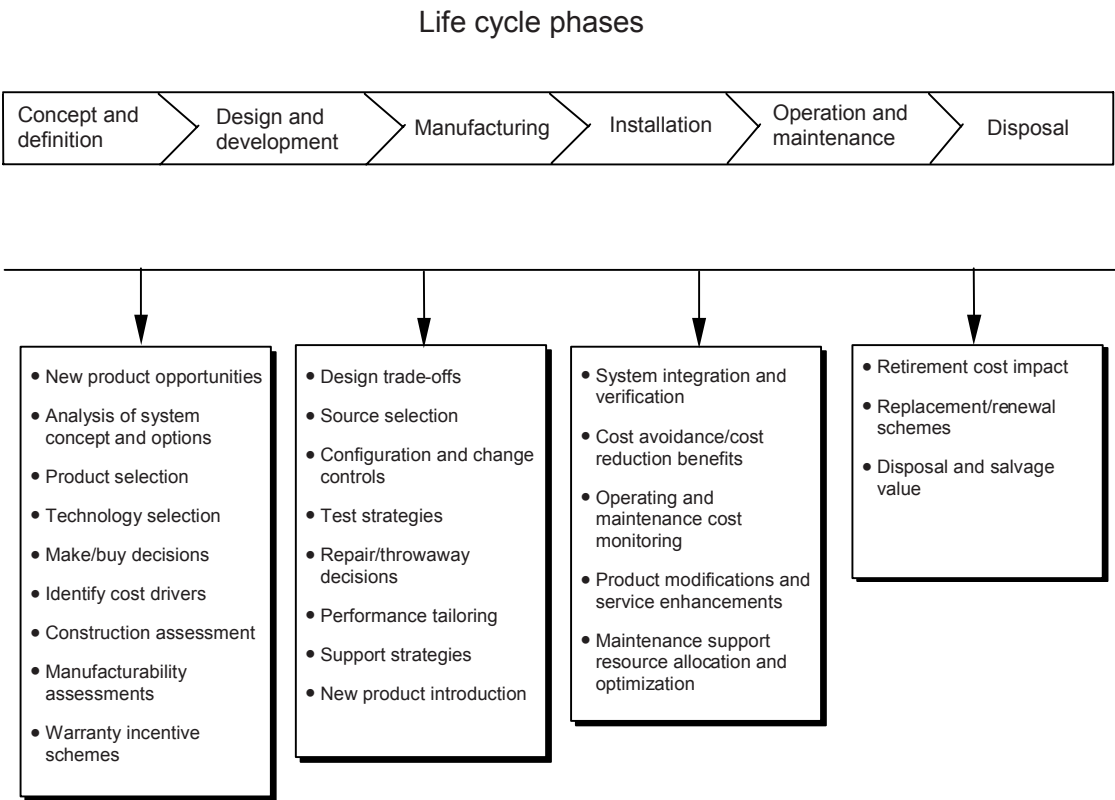
$$LCC = Cost_{acquisition} + Cost_{ownership} + Cost_{disposal}$$

Acquisition costs are generally visible, and can be readily evaluated before the acquisition decision is made and may or may not include installation cost.

The ownership costs, which are often a major component of LCC, in many cases, exceed acquisition costs and are not readily visible. These costs are difficult to predict and may also include the cost associated with installation.

Disposal costs may represent a significant proportion of total LCC. Legislation may require activities during the disposal phase that for major projects, e.g. nuclear power stations, involve a significant expenditure.

Figure 1 shows the life cycle phases of a product, together with some of the topics that should be addressed by a life cycle costing study.



IEC 715/04

Figure 1 – Sample applications of life cycle costing

4.3 Timing of LCC analysis

Early identification of acquisition, ownership and disposal costs enables the decision-maker to balance dependability factors against life cycle costs. Decisions made early in a product's life cycle have a much greater influence on LCC than those made later in a product's life cycle. Experience has shown that by the end of the concept and definition phases, more than half of a product's LCC may be committed by decisions. The opportunity to perform trade-offs becomes increasingly limited as the product advances in its life cycle.

Life cycle costing may address the whole life cycle of a product or only part of it. The life cycle costing should be tailored to suit a particular product/project in order to obtain the maximum benefit from the analysis effort.

4.4 Dependability and LCC relationship

4.4.1 General

Dependability of a product is the collective term used to describe the product's availability performance and its influencing factors, i.e. reliability performance, maintainability performance and maintenance support performance. Performance in all these areas can have a significant impact on the LCC. Higher initial costs may result in improved reliability and/or maintainability, and thus improved availability with resultant lower operating and maintenance costs.

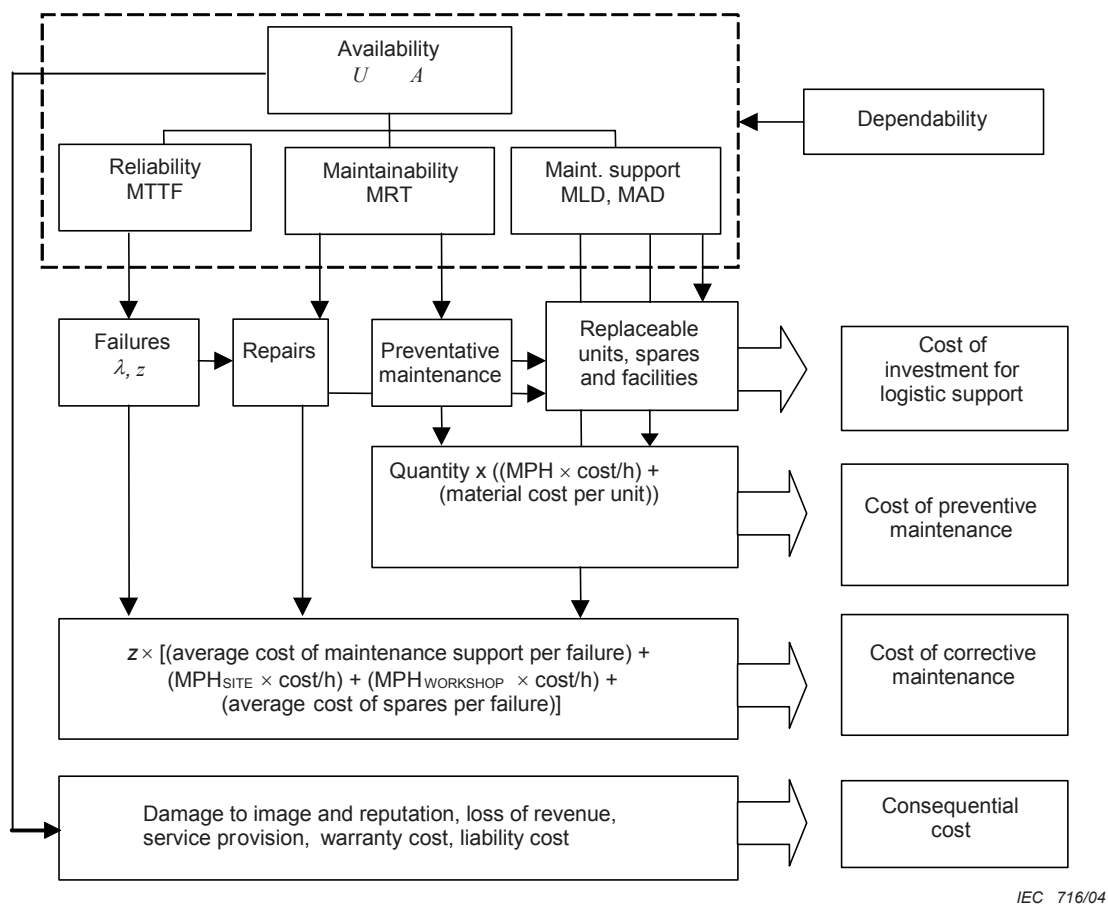
Dependability considerations should be an integral part of the design process and LCC evaluations. These considerations should be critically reviewed when preparing product specifications, and be continually evaluated throughout the design phases in order to optimize product design and the life cycle cost.

4.4.2 Dependability related costs

Costs associated with dependability elements may include the following, as appropriate:

- system recovery cost including corrective maintenance cost;
- preventive maintenance cost;
- consequential cost.

Figure 2 highlights some dependability elements translated into operation and maintenance costs.



Symbols and abbreviations apply in accordance with IEC 60050(191).

Figure 2 – Typical relationship between dependability and LCC for the operation and maintenance phase

4.4.3 Consequential costs

4.4.3.1 General

When a product or service becomes unavailable, a series of consequential costs may be incurred. These costs may include:

- warranty cost;
- liability cost;
- cost due to loss of revenue;
- costs for providing an alternative service.

In addition, further consequential costs should be identified by applying risk analysis techniques to determine costs of adverse impacts on the company's:

- image,
- reputation,
- prestige,

which in turn may result in loss of clients.

Costs of recovering from, or mitigating against these risks should be included in consequential costs.

In most cases, these costs are difficult to assess, but sometimes it is possible to quantify them. For example, these costs may be estimated based on publicity campaign costs and costs of marketing efforts or compensations in order to retain the clients. Where applicable, these costs should be accounted for.

The unavailability of a product can significantly affect its LCC. Therefore, the availability performance of a product and associated life cycle cost needs to be optimized. With increasing reliability (all other factors held constant), the acquisition costs will generally increase but maintenance and support costs will decrease. The LCC is optimized when the incremental increase in acquisition costs due to reliability improvements equals the incremental savings in maintenance and support costs, and in consequential costs. At a certain point, an optimum product reliability, which corresponds to the lowest life cycle cost, is achieved.

It should be noted that the results of LCC calculations might not match the actual/observed costs. This is because there are many influencing random factors, such as environmental conditions and human errors during operation, which cannot be accurately modelled in the calculations.

Environmental issues, as well as traditional factors such as cost and time, have to be considered in LCC calculations. Therefore, methods have to be used to evaluate and rank environmental consequences of different activities. These evaluations can provide the bases for environmental planning and integrating environmental issues with decision making.

4.4.3.2 Warranty costs

Warranties provide protection to the customers, insulating them from the cost of correcting product failures, in particular during the early stages of product operations. The cost of warranties is usually borne by the suppliers, and may be affected by reliability, maintainability and maintenance support characteristics of the product. Suppliers can exercise significant control over these characteristics during design and development, and manufacturing phases thus influencing the warranty costs.

Warranties usually apply for a limited period of time, and a number of conditions generally apply. Warranties rarely include protection against consequential costs incurred by the customer due to product unavailability.

Warranties may be supplemented or replaced by service contracts whereby the supplier performs, in addition to any arrangements made by the customer, all preventive and corrective maintenance for a fixed period of time that can be renewed for any period up to the whole product lifetime. In the latter case, the suppliers are motivated to build an optimum level of reliability and maintainability into their product, usually at higher acquisition costs.

4.4.3.3 Liability costs

A liability will arise where, for example, a supplier fails to comply with his legal obligations. The cost of compensating for a breach of the law needs to be considered as part of the LCC. This is especially important in the case of products that have a high potential to cause human injury and/or environmental damage. Liability costs are also important for new products for which risks involved may not be fully apparent and/or well understood. Where required, a risk analysis, together with past experience and expert judgement, may be used to provide an estimate of these costs. For guidance on risk analysis, see IEC 62198.

4.5 LCC concept

4.5.1 General

An LCC model, like any other model, is a simplified representation of the real world. It extracts the salient features and aspects of the product and translates them into cost estimating relationships. In order for the model to be realistic, it should:

- a) represent the characteristics of the product being analysed, including its intended use environment, maintenance concept, operating and maintenance support scenarios as well as any constraints or limitations;
- b) be comprehensive in order to include and highlight all factors that are relevant to LCC;
- c) be simple enough to be easily understood and allow for its timely use in decision making, and future update and modification;
- d) be designed in such a way as to allow for the evaluation of specific elements of LCC independent from other elements.

A simple LCC model is basically an accounting structure that contains mathematical expressions for the estimation of cost associated with each of the cost elements constituting the LCC. Examples are given in Annex D.

In some cases, a model may need to be specifically developed for the problem under study, while for some other cases commercially available models may be used. Each LCC model has its own flexibility and application. Knowledge of the contents and the conditions under which they apply are important in order to assure adequacy of their use. Before selecting a model, the amount of information needed should be identified together with the results expected from using the model. Someone familiar with the details of the model is needed to review it so as to determine the applicability of all cost factors, empirical relationships, elements and other constants and variables in the model. Therefore, before using any existing LCC model, it should be suitably validated for the life cycle costing study under consideration. To do this, the cost factors and other parameters from a known example, along with the operational scenario, should be used to assess the extent to which the model provides realistic results.

Many products are designed to have a very long life, for example buildings or power stations. For such products, a number of costs, for instance for functional changes or product enhancement, will occur at intervals during the life of the product and techniques to deal with these should be incorporated in the model.

LCC modelling includes:

- cost breakdown structure,
- product/work breakdown structure,
- selection of cost categories,
- selection of cost elements,
- estimation of costs,
- presentation of results.

When applicable it may also include:

- environmental and safety aspects,
- uncertainties and risks,
- sensitivity analysis to identify cost drivers.

The cost breakdown structure presents a breakdown of costs incurred over the major phases (or phases of interest) of the life cycle of a product. Annex C includes examples of presentation of costs related to cost breakdown structure.

The product/work breakdown structure is composed of a detailed breakdown of hardware, services and data identifying all major tasks and supporting work packages. Annex E gives an example of a product breakdown structure and LCC summary for a railway vehicle.

Detailed expressions for costs for the different phases can be developed separately. The cost elements, factors, etc. should have unique identities. In a situation where analyses cover several phases, the identities of cost elements, factors, etc. should be unique in the total LCC model. It is normally an advantage to maintain the product/work breakdown structure unvaried for the particular study.

4.5.2 LCC breakdown into cost elements

In order to estimate the total life cycle cost, it is necessary to break down the total LCC into its constituent cost elements. These cost elements should be individually identified so that they can be distinctly defined and estimated. The identification of the elements and their corresponding scope should be based on the purpose and scope of the LCC study.

The cost element is the link between cost categories and the product/work breakdown structure. The selection of cost elements should be related to the complexity of the product, as well as to the cost categories of interest in accordance with the required cost breakdown structure. See the example in Annex C.

One approach often used to identify the required cost elements involves the breakdown of the product to lower indenture levels, cost categories and life cycle phases. This approach can best be illustrated by the use of a three-dimensional matrix shown in Figure 3. This matrix involves identification of the following aspects of the product:

- breakdown of the product to lower indenture levels (i.e. the product/work breakdown structure);
- the time in the life cycle when the work/activity is to be carried out (i.e. the life cycle phases);
- the cost category of applicable resources such as labour, materials, fuel/energy, overhead, transportation/travel (i.e. the cost categories).

This kind of approach has the advantage of being systematic and orderly, thus giving a high level of confidence that all cost elements have been included.

Annex A identifies typical activities for which the costs should be addressed.

An example of a product breakdown structure and LCC summary for a railway vehicle is presented in Annex E.

Costs associated with LCC elements may be further allocated between recurring and non-recurring costs so that the total of all recurring and non-recurring costs equals LCC. LCC elements may also be estimated in terms of fixed and variable costs. The latter costs, for example, will vary with the number of copies of the product to be produced and put into use.

To facilitate control and decision making, and to support the life cycle cost process, the costs information should be collected and reported to be consistent with the defined LCC breakdown structure. A database should be established and maintained to capture results of previous LCC studies in order to serve as a source of experience feedback.

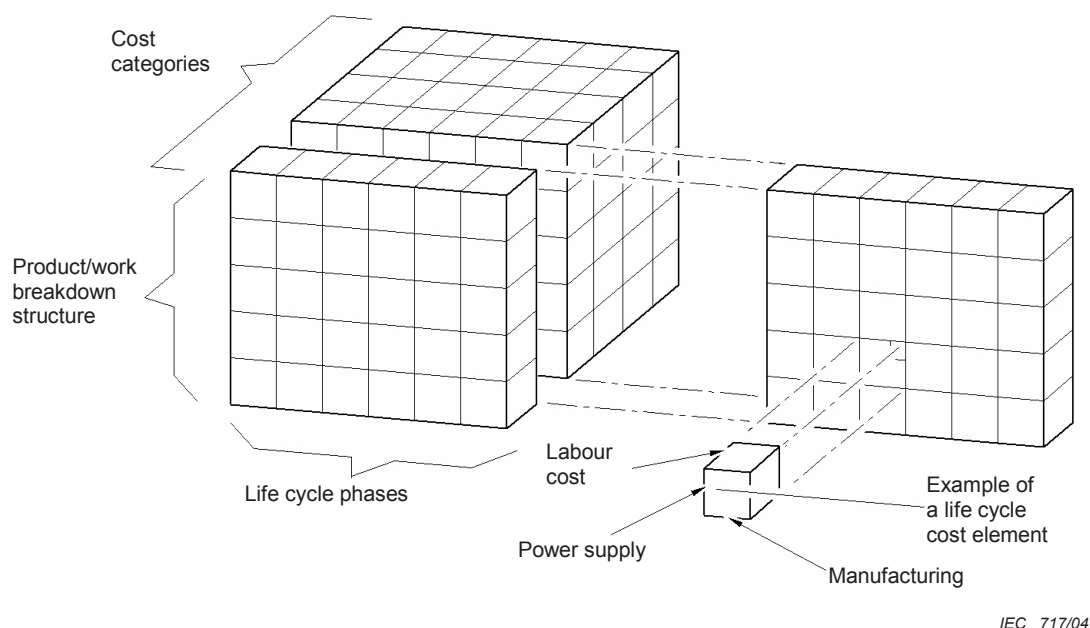


Figure 3 – Cost element concept

4.5.3 Estimation of cost

4.5.3.1 General

Examples of methods that may be used to estimate the parameters of a cost element include:

- engineering cost method;
- analogous cost method;
- parametric cost method.

Examples of application of each method are given below.

When carrying out life cycle costing analysis for a certain product, one or more of these methods, or other methods, may be used as appropriate.

In order to reduce different types of uncertainties involved in the analyses, it should be possible to perform sensitivity analyses, for example by introducing minimum and maximum values to the parameters of the model into the cost estimation equations.

4.5.3.2 Engineering cost method

When using the engineering cost method, the cost attributes for the particular cost elements are directly estimated by examining the product component by component or part by part. Often, standard established cost factors, e.g. the current engineering and manufacturing estimates, are used to develop the cost of each element and its relationship to other elements. Older estimates available may be updated to the present time by the use of appropriate factors, e.g. annual discounting and escalation factors.

The engineering cost method can be illustrated by the following example concerning the cost related to a recurring cost element:

The labour cost for the manufacture of a power supply is to be estimated. The following information is given:

Product: power supply
 Life cycle phase: manufacturing phase
 Cost category: labour cost.

According to detailed assessment of manufacturing steps provided by the manufacturing department, the time consumption for the production of one unit of the particular power supply is 38,80 person hours. Suppose the labour cost is currency unit (CU) 54,50/person hours. The total labour cost for the production of one unit is then $38,80 \times 54,50 = \text{CU } 2\,114,60$.

4.5.3.3 Analogous cost method

In this method, cost estimations based on experience from a similar product or technology are used. Historical data, updated to reflect cost escalation, effects of technology advances, etc. are utilized. This technique may be one of the least complex and least time-consuming methods. It is easily applied to components of the product for which there is some experience and actual data.

The analogous cost method can be illustrated by the following example where an estimate of the cost for parts and materials for a power supply, using experience from an older power unit, is used.

The following information is given:

Product: power supply
 Life cycle phase: manufacturing phase
 Cost category: parts and materials.

For a somewhat less complex power supply produced 4 years ago, the cost for parts and materials was CU 220. Overall cost escalation over 4 years is taken to be 5 %.

The cost for additional parts will be about CU 50.

Therefore, cost for parts and materials for the new power supply unit is estimated to be

Cost of parts and material for the old unit $(1+0,05)$ + cost for additional parts =
 $= 220 \times 1,05 + 50 = \text{CU } 281$.

4.5.3.4 Parametric cost method

The parametric cost method uses parameters and variables to develop cost estimating relationships. The method might be used differently in other areas.

The relationships are usually in the form of equations where, for example, person hours are converted into costs.

An example of the parametric cost method used for a calculation of active corrective maintenance cost for a subsystem P_{14} , is given in Figure 4.

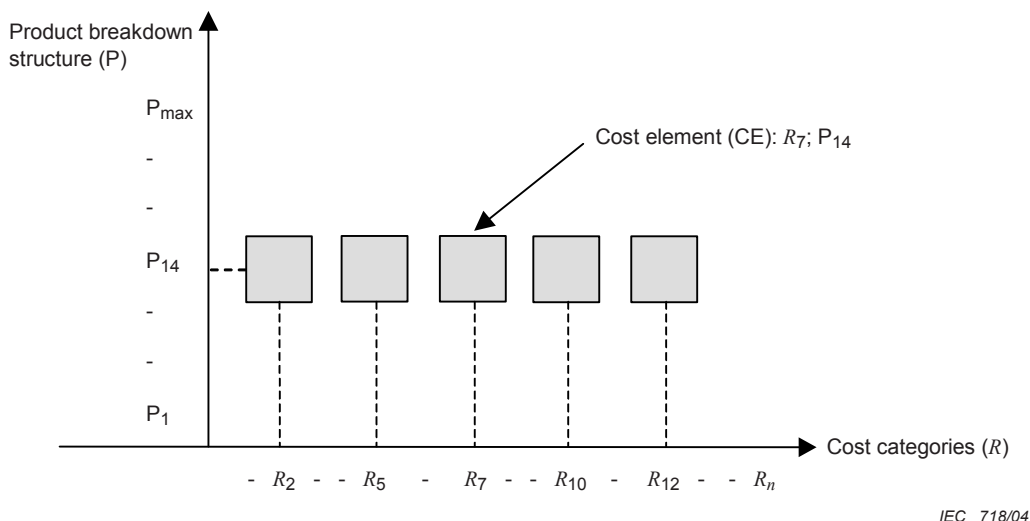


Figure 4 – Example of cost elements used in the parametric cost method

In Figure 4

- R_2 is the investment cost in test equipment, workshop (non-recurring);
- R_5 is the investment cost in spares, workshop (non-recurring);
- R_7 is the labour cost, site (recurring);
- R_{10} is the labour cost, workshop (recurring);
- R_{12} is the spares consumption cost, workshop (recurring);
- P_{14} is subsystem P_{14} .

Cost of active corrective maintenance for subsystem P_{14} for a 10 year period =

$$\text{Cost}(R_2; P_{14}) + \text{Cost}(R_5; P_{14}) + \{\text{Cost}(R_7; P_{14}) + \text{Cost}(R_{10}; P_{14}) + \text{Cost}(R_{12}; P_{14})\} \times 10$$

(ignoring the effects of inflation, etc.)

NOTE Active corrective maintenance time is defined in IEC 60050(191), see definition 191-08-07 and Figure 191-10.

where, for example, the cost related to element ($R_7; P_{14}$) is calculated as follows:

$$\begin{aligned} \text{Cost}(R_7; P_{14}) &\text{ is the labour cost, active corrective maintenance at site for sub-system } P_{14} \\ \text{Cost}(R_7; P_{14}) &= QP_{14} \times ZP_{14} \times C_L \times n \times \text{MRT cost/year} \end{aligned}$$

where

- QP_{14} is the quantity or number of items, in this example $QP_{14} = 1$;
- ZP_{14} is the expected number of failures/year for subsystem P_{14} ;
- C_L is the labour cost/hour;
- n is the number of persons required to carry out the repair;
- MRT is the mean repair time in h/action.

Assume:

- $QP_{14} = \text{one item /system}$
- $ZP_{14} = 0,3 \text{ failures/year}$
- $C_L = \text{CU } 50/\text{hour}$
- $n = \text{one person}$

MRT = 2,4 h/action.

Then

$$\text{Cost}(R_7; P_{14}) = 1 \times 0,3 \times 50 \times 1 \times 2,4 = \text{CU } 36/\text{year}.$$

To calculate the labour cost over 10 years, the result should be multiplied by 10 (ignoring the effects of inflation, etc.).

If different factors, for instance inflation or discounting, have to be taken into account, this could be included in the estimation of cost related to each element or at a higher cost element level in the LCC model.

$\text{Cost}(R_{10}; P_{14})$, etc. are calculated in a similar way.

4.5.4 Sensitivity analysis

In order to identify significant cost contributors, sensitivity analyses should be performed. Data may be varied to establish their impact on the total LCC or part of it.

To facilitate the sensitivity analysis, it is important that the LCC model is developed in such a manner that, when a common parameter, for instance person hour cost, is varied, this is automatically reflected wherever this parameter is used.

It may be desirable to use minimum or maximum values of certain data or even a distribution. The LCC model in that case should be developed to meet these needs.

4.5.5 Impact of discounting, inflation and taxation on LCC

Several factors complicate the life cycle costing process; for example, the real value of money changes constantly and factors such as opportunity costs, inflation and taxation may need to be taken into account.

Annex B introduces these concepts and briefly indicates the methods that may be used to take account of them.

4.6 Life cycle costing process

4.6.1 General

The life cycle costing process involves identification and evaluation of the costs associated with acquisition, ownership and disposal of a product during its life cycle. In order to produce results which can be usefully and correctly employed, any life cycle costing analysis should be conducted in a structured and well-documented manner using the following steps:

- a) life cycle costing plan (including definition of life cycle costing objectives);
- b) LCC model selection or development;
- c) LCC model application;
- d) life cycle costing documentation;
- e) review of life cycle costing results;
- f) analysis update.