BRITISH STANDARD

BS 5760-23:
1997
IEC 300-3-3:
1996

Reliability of systems, equipment and components —

Part 23: Guide to life cycle costing

ICS 29.020

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee DS/1, Reliability and maintainability systems, upon which the following bodies were represented:

Association of Consulting Engineers
Association of Project Managers
British Gas plc
British Railways Board
British Telecommunications plc
Chartered Institution of Building Services Engineers
City University
Civil Aviation Authority
Consumer Policy Committee of BSI
Cranfield University
Defence Manufacturers' Association
Department of Trade and Industry (Standards Policy Unit)
Electricity Association
Federation of the Electronics Industry
GAMBICA (BEAMA Ltd.)
Institute of Logistics
Institute of Quality Assurance
Institute of Risk Management
Institute of Value Management
Institution of Electrical Engineers
Institution of Mechanical Engineers
Institution of Plant Engineers
London Underground Ltd.
Loughborough University
Mercury Communications Limited
Ministry of Defence
National Computing Centre Ltd.
Railtrack
Railway Industry Association
Royal Institution of Chartered Surveyors
Safety and Reliability Society
Society of Environmental Engineers
Society of Environmental Engineers
Society of Motor Manufacturers and Traders Limited
United Kingdom Cals Industry Council
University of Bradford
West Midlands Enterprise Board

This British Standard, having been prepared under the direction of the Management Systems Sector Board, was published under the authority of the Standards Board and comes into effect on 15 February 1997

The following BSI references relate to the work on this standard:
Committee reference DS/1
Draft for comment 95/402058 DC

ISBN 0 580 27131 5

Amendments issued since publication

Amd. No.	Date	Comments

Contents

National foreword

This Part of BS 5760 has been prepared by the Technical Committee DS/1 and is identical with IEC 300-3-3:1996 *Dependability management — Part 3: Application guide — Section 3: Life cycle costing*, published by the International Electrotechnical Commission (IEC).

This standard gives a general introduction to the concept of life cycle costing.

BS 5760 provides comprehensive guidance on many aspects of reliability management. The Parts so far published are as follows:

— *Part 0: Introductory guide to reliability*;

— *Part 1: Dependability programme elements and tasks;*

— *Part 2: Guide to the assessment of reliability;*

— *Part 3: Guide to reliability practices: examples*;

— *Part 4: Guide to specification clauses relating to the achievement and development of reliability in new and existing items*;

— *Part 5: Guide to failure modes, effects and criticality analysis (FMEA and FMECA)*;

— *Part 6: Guide to programmes for reliability growth*;

— *Part 7: Guide to fault tree analysis*;

— *Part 9: Guide to the block diagram technique*;

— *Part 10: Guide to reliability testing*;

— *Section 10.1: General requirements;*

— *Section 10.2: Design of test cycles*;

— *Section 10.3: Compliance test procedures for steady-state availability*;

— *Section 10.5: Compliance test plans for success ratio*;

— *Part 11: Collection of reliability, availability, maintainability and maintenance support data from the field*;

— *Part 12: Guide to the presentation of reliability, maintainability and availability predictions*;

— *Part 13: Guide to reliability test conditions for consumer equipment*;

— *Section 13.1: Conditions providing a low degree of simulation for indoor portable equipment*;

— *Section 13.2: Conditions providing a high degree of simulation for equipment for stationary use in weather-protected locations;*

— *Section 13.3: Conditions providing a low degree of simulation for equipment for stationary use in partially weather-protected locations*;

— *Section 13.4: Conditions providing a low degree of simulation for equipment for portable and non-stationary use*;

— *Section 13.5: Ground mobile equipment — Low degree of simulation*;

— *Section 13.6: Test cycle 6: Outdoor transportable equipment — Low degree of simulation*;

— *Part 14: Guide to formal design review*;

— *Part 15: Guide to the application of Markov techniques*;

— *Part 16: Guide to stress screening*;

— *Section 16.1: Repairable items manufactured in lots*;

— *Part 17: Reliability growth — Statistical test and estimation methods*;

— *Part 18: Reference conditions for failure rates of electronic components and stress models for conversion*;

— *Part 20: Guide to the specification of dependability requirements.*

Further Parts of BS 5760 are envisaged in order to provide guidance on other techniques of reliability management.

NOTE Part 8: *Guide to the assessment of reliability of systems containing software* is currently in preparation and is available as DD 198:1991.

Whilst mainly addressing system and equipment level reliability, many of the techniques described in the Parts of BS 5760 may also be applied at the component level. Further guidance on component reliability is given in BS CECC 00804:1996.

Cross-references

The British Standards which correspond to international or European publications referred to in this document may be found in the current BSI Catalogue under the section entitled "International Standards Correspondence Index".

The Technical Committee has reviewed the provisions of IEC 300-2:1995, to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 14 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

blank

Introduction

Today's customers require products that are reliable, that perform their functions safely and that can be easily maintained over their useful lives. Their decision to purchase is not only influenced by the product's initial cost (acquisition cost) but also by the product's expected operating cost and maintenance cost over its life (ownership cost). In order to achieve customer satisfaction, the challenge for suppliers is to design products that are reliable and cost competitive by optimizing acquisition and ownership costs. This optimization process ideally should 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 about a product's design and manufacture may affect its performance, safety, reliability, maintainability, maintenance support requirements, etc., and ultimately determine its price and ownership cost.

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

Life cycle cost analysis is most effectively applied in the product's early design phase to optimize the basic design approach. However, it should also be used during the subsequent phases of the life cycle to optimize other engineering decisions and facilitate efficient allocation of resources.

Formal application of the life cycle costing process to a product will depend on customer/contract requirements. However, life cycle cost analysis 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.

1 Scope

This section of IEC 300-3 provides a general introduction to the concept of life cycle costing. Although the life cycle costs consist of many contributing elements, this standard particularly highlights the costs associated with dependability of the product.

It 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 for conducting a life cycle cost analysis, including life cycle cost model development, is provided.

NOTE Further supporting sections to this standard are under consideration.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 300-3. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 300-3 are encouraged to investigate the possibility of applying the most recent editions of the normative documents listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(191):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service.*

IEC 300-1/ISO 9000-4:1993, *Dependability management — Part 1: Dependability programme management.*

IEC 300-2:1995, *Dependability management — Part 2: Dependability programme elements and tasks.*

ISO 9004-1:1994, *Quality management and quality system elements — Part 1: Guidelines.*

ISO 8402:1994, *Quality management and quality assurance — Vocabulary.*

3 Definitions

For the purpose of this section of IEC 300-3 the terms and definitions of IEC 50(191) and ISO 8402 apply. In addition, the following terms and definitions are used:

3.1
life cycle

time interval between a product's conception and its disposal

3.2
life cycle cost (LCC)

cumulative cost of a product over its life cycle

3.3
life cycle costing

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

3.4
cost driver

LCC element which has a major impact on the LCC

3.5
cost profile

graphical or tabular representation showing the distribution of costs over the life cycle (or portion thereof) of a product

3.6
life cycle cost breakdown structure

ordered breakdown of the elements of cost to arrive at a product's total life cycle cost

4 Life cycle cost concept

4.1 Objectives of life cycle costing

The primary objective of life cycle costing is to evaluate and/or optimize a product's life cycle costs while satisfying specified performance, safety, reliability, maintainability and other requirements. The aim is to provide input to decision making in all phases (especially in early phases) of a product's life cycle. The more common types of decisions to which the life cycle costing process is used to provide input include, for example:

— evaluation and comparison of alternative design approaches;

— assessment of economic viability of projects/products;

— identification of cost drivers 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.

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, and resulting life cycle costs.

There are six major life cycle phases of a product (as defined in IEC 300-2):

a) concept and definition;

b) design and development;

c) manufacturing;

d) installation;

e) operation and maintenance;

f) disposal.

The total costs incurred during the above phases can be divided into two major areas, namely, acquisition costs and ownership costs. Hence, by definition:

$$\mathbf{LCC = Cost_{acquisition} + Cost_{ownership}}$$

Acquisition costs are incurred generally during the first four life cycle phases and are of concern both to the supplier and to the customer. Ownership costs are incurred during the last three phases. Although the latter costs are of prime concern to the product user, that is the customer, they are increasingly becoming a concern of the supplier as well, through the use of extended warranty type agreements and other contractual arrangements. The acquisition costs are generally visible, and can be readily evaluated before the acquisition decision is made. However, the ownership costs, which often are a major component of LCC, and in many cases exceed acquisition costs, are not readily visible and are difficult to predict. Lack of visibility of these costs (which include costs associated with safety, reliability, maintainability, maintenance support performance) in early design phases creates uncertainty and risk in the decision making process.

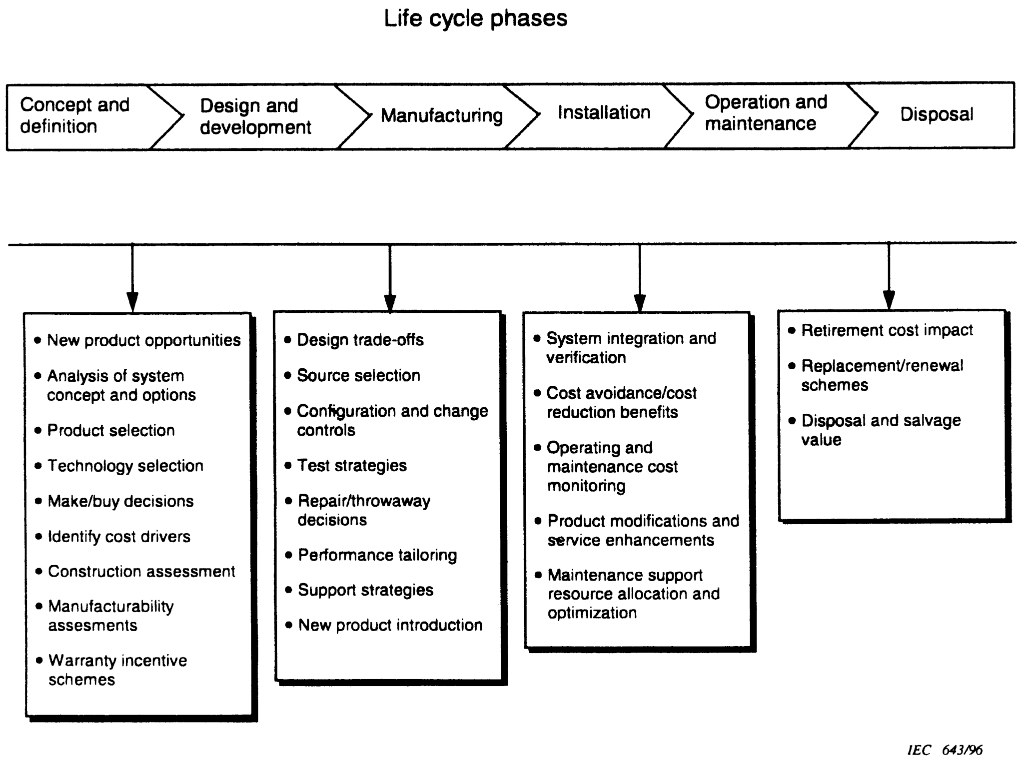

Figure 1 — Sample applications of LCC

The life cycle phases identified above apply to new products and do not necessarily apply to those that are well developed. Therefore, for estimating life cycle cost, the life cycle phases for the product under consideration should be clearly defined to allow identification of various activities that involve costs over the various life cycle phases.

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.

4.3 Timing of life cycle costing

Life cycle cost analysis can be carried out in any and all phases of a product's life cycle to provide input to decisions regarding product concept, design, manufacture, installation, operation, maintenance and disposal. However, early identification of acquisition and ownership costs enables the decision maker to balance performance, reliability, maintainability, maintenance support and other goals 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 product LCC may be determined by decisions made with respect to product features, performance, reliability, technology and support resources. By the end of the design and development phase, even more of product LCC may be fixed. The product is locked into a fairly rigid system of hardware and software configuration, operation, and maintenance support. This clearly implies that the timing of the LCC analysis is very crucial to optimize the product and its associated costs. The flexibility in design trade-offs and options becomes increasingly limited as the product advances in its life cycle.

The life cycle cost process can be applied to the whole life cycle of a product or to a part of it. In the latter case, a partial estimate of the overall life cycle cost will be obtained, although it will not provide for LCC optimization. Such estimates are useful as they permit specific focus on comparative studies where only the cost differentials in various alternatives are to be assessed and compared. The period of life over which the life cycle costing analysis is made should be tailored to suit a particular product/project in order to obtain the maximum benefit from the analysis effort.

5 Dependability and LCC relationship

5.1 General

Dependability of a product is a collective term which is used to describe the product's availability performance and its influencing factors, such as 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. For example, it may be less expensive to use higher quality parts or part deratings in order to incur lower failure and maintenance costs during its operation phase.

Reliability, maintainability and other dependability management 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 to the lowest life cycle cost.

Costs associated with product safety, reliability, maintainability and maintenance support performance, which are not that apparent, but need to be accounted for in life cycle cost models, may include the following, as appropriate:

— unavailability costs (including costs associated with loss of product function);

— warranty costs and costs for warranty-type agreements;

— liability costs.

These costs are explained further in the following subclauses.

5.2 Unavailability costs

Unavailability of a product is influenced by its reliability, maintainability and maintenance support resources. The product may be unavailable because of a hardware or software failure or a human error, or because of preventive maintenance (which requires the product to be taken out of service). There are labour, materials and other support costs associated with these activities. The costs of unavailability may include:

— cost of corrective maintenance;

— cost of preventive maintenance;

— the cost associated with the loss of product's function during the period of its unavailability.

The latter cost, sometimes also referred to as consequential costs, can be quite significant in the case of products performing critical functions where the penalties for loss of the product's function are very high. The penalties consist of either loss of income to the user through failure of the product to deliver its output or additional costs arising from the user having to take actions to compensate for the loss of the product's output. In some instances, the cost associated with loss of product function may be significantly influenced by the frequency of failures (that is reliability) whereas for some other products, both failure frequency (reliability) and restoration time (maintainability and maintenance support) may be important. The factors that affect the cost associated with the loss of the product's function include:

a) differences in the pattern and extent of actual failures and downtimes, and those for which the individual user had planned and catered for;

b) the actual circumstances in which the failure and downtime occur, especially in regard to the demand placed on the user for the output of that product and all other alternative sources open to him;

c) the ability or otherwise to restore the output of the product;

d) the consequences to, and the reaction by, the user's own customer(s) as a result of delay to the product.

NOTE Unavailability costs could also include costs related to the loss of image and prestige of the company or the loss of clients, caused by some specific failures. 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 needs to be optimized in order to obtain the lowest LCC. This conceptual relationship between availability (reliability, maintainability and maintenance support) and the LCC in a simplified form is illustrated in Figure 2. It shows that with increasing reliability (all other factors held constant), the acquisition costs will generally increase but maintenance and support costs will decrease. The LCC is minimized 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.

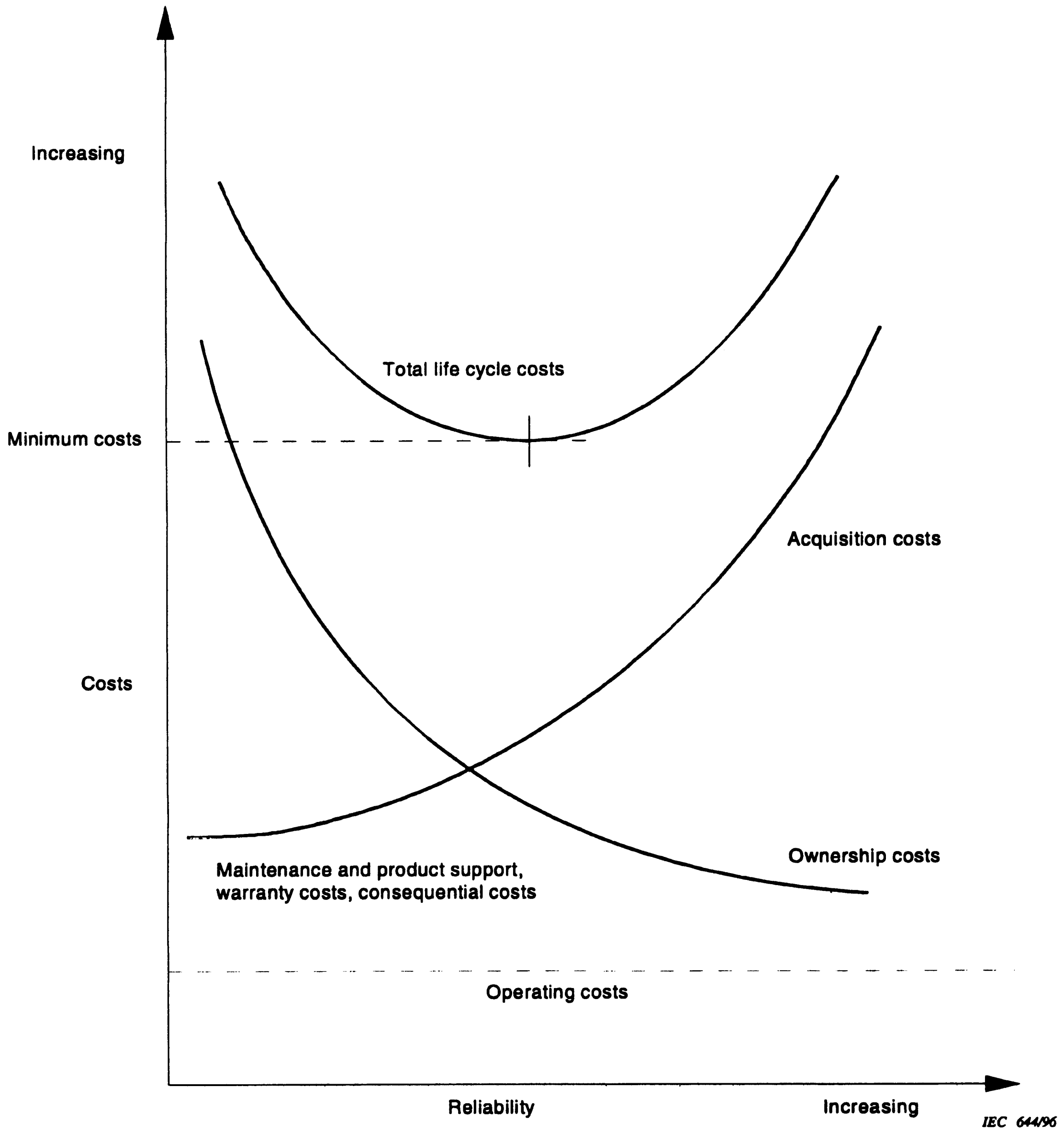

Figure 2 — Simplified relationship between reliability and life cycle costs

5.3 Warranty costs

Warranties provide protection to the customers, guarding 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 depends on 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 to a limited period of time and a number of conditions generally apply. Warranties rarely include protection against the service losses incurred by the customer (that is the consequential costs) 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 which can be extended for monetary considerations for any period up to the whole product lifetime. In the latter case, the burden for the major part of life cycle costs is placed on the supplier who, to maximize his profit, is motivated to build an optimum level of reliability and maintainability into his product, probably at higher acquisition costs.

5.4 Liability costs

Cost of liabilities due to product failure and their injurious effects need to be considered as part of the LCC. This is especially important in the case of products which 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. These costs are generally difficult to quantify. Where required, a risk analysis, together with past experience and expert judgement, may be used to provide an estimate of these costs.

6 LCC modelling

6.1 General

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

a) represent the characteristics of the product being analyzed, including its intended use environment, maintenance concept, operating and maintenance support scenarios, and 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 which contains terms and/or factors which allow for the estimation of cost associated with each of the cost elements constituting the LCC.

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 (see **6.3**). 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 very long life, for example buildings. For such products, a number of costs will occur at intervals during the life of the product and techniques to deal with these should be incorporated in the model.

6.2 LCC breakdown into cost elements

In order to estimate the total life cycle cost, it is necessary to breakdown 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.

One approach, often used to identify the required cost elements, involves the breakdown of the product to lower indenture levels (work breakdown structure), 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 (that is the product/work breakdown structure);

— the time in the life cycle when the work/activity is to be carried out (that is the life cycle phases);

— the cost category of applicable resources such as labour, materials, fuel/energy, overhead, transportation/travel, etc. (that is 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 the costs of which should be addressed.

Costs associated with LCC elements may be further allocated between recurring and non-recurring costs so that the sum 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 data base should be established and maintained to capture results of previous LCC studies, in order to serve as a source of experience feedback.

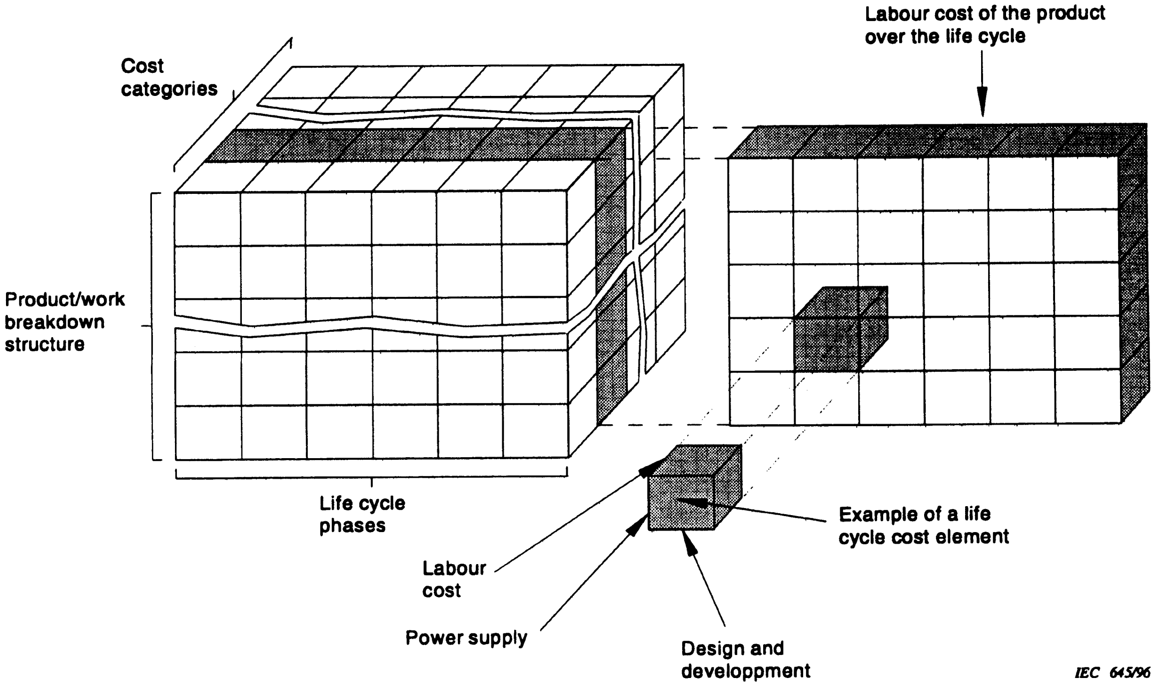

Figure 3 — Cost element concept

6.3 Methods for estimating cost elements

Cost estimating relationships (CERs) are used to estimate the cost related to individual elements of LCC breakdown structure. CERs are either based on analytical models or "rules of thumb". They contain variables describing resource consumption, and parameters reflecting prices, conversion factors, or empirical relationships relating various categories of cost to cost generating activities/tasks. These relationships range from simple averages and percentages to complex equations, resulting from statistical regression analysis, which relate cost (the dependent variable) to the product's physical features, and such characteristics as performance, reliability, maintainability, etc.

In general, there are three basic methods that are commonly used to estimate cost or to develop CER. They are:

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

6.3.1 *Engineering cost method*

This method involves the direct estimation of a particular cost element by examining the product component-by-component or part-by-part. It uses standard established cost factors, for example firm engineering and manufacturing estimates to develop the CERs. Any old estimates available should be updated to the present time by the use of annual discounting and escalation factors (see **6.4**).

6.3.2 *Analogous cost method*

This method involves cost estimation based on experience with a similar product and technology in the past. It utilizes historical data from a dependability information system, updated to reflect cost escalation and effect of technology advances.

6.3.3 *Parametric cost method*

This method uses significant parameters and variables to develop CERs which are usually in the form of equations. A parameter in CERs reflects a conversion factor from one system of units to another. It may be a price or an empirically derived ratio. A price like cost per man-hour, for example, converts person hours into costs. An example of an empirical ratio is the number of maintenance person-hours per failure of a given component, which may be obtained as a statistical average.

A variable in the CER of parametric cost methods generally characterizes resource consumption over time and generates cost. It may be a physical or performance measure, such as failure rate, preventive maintenance person-hours per unit of item or component.

The CER equation reflects analysts' assessment of how costs are generated. Often when a detailed theoretical or analytical relationship cannot be developed, a statistically derived relationship, for example via regression analysis, may be used.

6.4 Impact of discounting, inflation and taxation

6.4.1 *General*

Several factors complicate the process of LCC analysis; 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.

6.4.2 to **6.4.5** introduce some of these effects and briefly indicate the methods that may be used to take account of them.

6.4.2 *Discounting*

The value of money is not constant. For example, a dollar today is worth more than a dollar in ten years time. Similarly, the present value of a dollar that will be spent ten years from now is less than the value of today's dollar. Discounting is a process for taking account of the changing value of money. Since LCC analysis considers costs that will be incurred some time in the future, it is necessary to discount all revenues and expenditures to a specific decision point. This point may be either in the present or in the future. This process allows direct comparison of the life cycle costs of various alternatives.

The most common method of discounting involves calculation of net present value (NPV).

$$\mathrm{NPV} = \sum_{n=0}^{T} C_n (1 + X)^{-n}$$

where

NPV	is the net present value of future cash flows;
C_n	is the nominal cash flow in nth year;
n	is the specific year in the life cycle costing period;
X	is the discount rate;
T	is the length of time period under consideration, in years.

6.4.3 ***Escalating***

Escalating takes account of the change in price levels over time. The common formula for determining the escalation factor (EF) in year n considering the escalation rate in i'th year to be E_i is:

$$EF = (1 + E_1) \times (1 + E_2) \times (1 + E_3)...(1 + E_n)$$

Standard tables of discounting and escalation factors are available in most engineering and economic textbooks to facilitate the calculations.

6.4.4 ***Opportunity costs***

In order to improve a product, it is often necessary to provide additional resources early in the life cycle. Thus, to achieve improved dependability and its consequent benefits, it may be necessary to provide extra resources, such as prototypes and test facilities, in the early stages of the project life cycle. However, it is important to realise that these resources represent funds that could, at least in theory, have been invested to earn a return on capital. The "opportunity" to earn this return is lost by the investment made to improve dependability. The lost return is known as an opportunity cost. The LCC analysis should take account of the lost opportunity cost when considering the benefits of improved dependability.

6.4.5 ***Inflation***

Due to the difficulties of accurately predicting inflation, it is usual for LCC analysis to be prepared at "constant prices". Sometimes, however, for example in the case of a short life cycle, it may be possible to predict or agree a rate of inflation to be included in the LCC analysis.

It is important to ensure that all cost elements and their dependencies that are affected by inflation are fully addressed, and that they are addressed only once in order to avoid "double counting".

6.4.6 ***Taxation***

Taxes and subsidies can affect relative prices. Market prices which include them may not reflect opportunity costs or benefits, for this and other reasons.

The adjustment of market prices, for taxation in LCC analysis is appropriate only where the adjustment may make a material difference. This is a matter for case by case judgement, but it is important to adjust for any differences between options in the incidence of tax arising from different contractual arrangements, such as in-house supply versus buying-in, or lease versus purchase.

7 Life cycle costing process

7.1 General

Life cycle cost (LCC) analysis is the process of identifying and evaluating the costs associated with acquisition and ownership of a product during its life cycle. In order to produce results which can be usefully and correctly employed, any LCC analysis should be conducted in a structured and well-documented manner using the following steps:

a) LCC analysis plan (including problem definition and analysis objective);

b) LCC model development;

c) LCC model analysis;

d) LCC analysis documentation;

e) review of LCC results;

f) LCC analysis update.

The above steps may be carried out in an iterative fashion if efforts at any stage indicate a need to revisit and modify work accomplished at earlier stages. Assumptions made at each step should be rigorously documented to facilitate such iterations and to aid in interpretation of the results of the analysis.

LCC analysis is a multidisciplinary activity. The analysts should be familiar with the philosophy which underlies LCC (including typical cost elements, sources of cost data and financial principles), and should have a clear understanding of the methods of assessing the uncertainties associated with cost estimation. Depending upon the scope of the analysis, it will be important to obtain cost inputs from individuals who are familiar with all phases of the product life cycle. This may include representatives of both the supplier(s) and the customer(s).

7.2 LCC analysis plan

The LCC analysis should begin with development of a plan which addresses the purpose and scope of the analysis. The plan should address the following elements:

a) define the analysis objectives in terms of the outputs that should be provided by the analysis, and the decisions which outputs will be used to support. Typical objectives are:

1) determination of the LCC for a product, in order to support planning, contracting, budgeting or similar needs;

2) evaluation of the impact of alternative courses of action (such as design approaches, product acquisition or support policies or alternative technologies) on the LCC of a product; or

3) identification of cost elements which act as cost drivers for the LCC of a product, in order to focus design, development, acquisition or product support efforts.

b) delineate the scope of the analysis in terms of the product(s) being studied, the time period (life cycle phases) to be considered, the use environment, the operating and maintenance support scenario to be employed;

c) identify any underlying conditions, assumptions, limitations and constraints (such as minimum product performance or availability requirements, or maximum capital cost limitations) which might restrict the range of acceptable options to be evaluated;

d) identify alternative courses of action to be evaluated (if this forms part of the analysis objective). The list of proposed alternatives may be refined as new options are identified, or as existing options are found to violate the problem constraints;

e) provide an estimate of resources required, and a reporting schedule for the analysis, to ensure that LCC analysis results will be available to support the decision-making processes for which they are required.

The analysis plan should be documented at the beginning of the LCC analysis process to provide a focus for the rest of the work. The plan should be reviewed by the intended users of the analysis results, both from a customer and a supplier perspective, to ensure that their needs have been correctly interpreted and clearly addressed.

7.3 LCC model development

An LCC model, of sufficient detail to meet the objectives of the analysis, should be developed in accordance with the following procedure:

a) create or adopt a cost breakdown structure (CBS) that identifies all relevant cost categories in all appropriate life cycle phases which will generate costs. Cost categories should be broken down into smaller components (activities, subactivities, etc.) until a required level is reached in the CBS where a cost can be readily estimated for each individual cost element. Where available, an existing cost breakdown structure may provide a useful starting point for development of the LCC breakdown structure (see **6.2**);

b) identify cost elements which will not have a significant impact on the overall LCC of the product(s) under consideration: these elements may be eliminated from further consideration. Similarly, for comparative studies of alternative courses of action, identify cost elements which will not vary between alternatives; these elements may be eliminated as they effect all options similarly;

c) select a method (or methods) for estimating the cost associated with each cost element to be included in the model (see **6.3**);

d) determine the data required to develop these estimates, and identify possible sources for the data;

e) identify any uncertainties which are likely to be associated with the estimation of each cost element;

f) integrate the individual cost elements into a unified LCC model which will provide the LCC outputs required to meet the analysis objectives, such as total LCC figures at the system level (and at lower levels, if required) and/or LCC figures over time. The model should take into account the time value of money;

g) review the LCC model to ensure that it is adequate to address the objectives of the analysis. Ensure that all cost elements have been included, that the elements are correctly rolled-up into higher-level totals, and that the time value of money is accurately reflected.

The LCC model including all assumptions should be documented to guide and support the subsequent phases of the analysis process.

7.4 LCC model analysis

The LCC analysis which involves the generation and analysis of LCC model results should include the following steps:

a) obtain data and develop cost estimates for all of the basic cost elements in the LCC model;

b) validate the LCC model with available historical data, if possible;

c) obtain the LCC model results from each relevant combination of operating and support scenarios defined in the analysis plan;

d) identify cost drivers by examining LCC model inputs and outputs to determine the cost elements which have the most significant impact on the LCC of the product(s);

e) quantify any differences (in performance, availability or other relevant constraints) between any alternatives being studied, unless these differences are directly reflected in the LCC model outputs (for example, through the evaluation of the cost of unavailability);

f) categorize and summarize LCC model outputs according to any logical groupings (for example, fixed or variable costs, recurring or non-recurring costs, acquisition or ownership costs, direct or indirect costs) which may be relevant to users of the analysis results;

g) conduct sensitivity analyses to examine the impact of assumptions and cost element uncertainties on LCC model results. Particular attention should be focused on cost drivers, assumptions related to product usage, and assumption related to the time value of money;

h) review LCC outputs against the objectives defined in the analysis plan to ensure that all goals have been fulfilled, and that sufficient information has been provided to support the required decision. If the objectives have not been met, additional evaluations and/or modifications to the LCC model may be required.

The LCC analysis (including all assumptions) should be documented to ensure that the results could be verified and readily replicated by another evaluator, if necessary.

7.5 LCC analysis documentation

The results of the LCC analysis should be documented in a report which allows users to clearly understand both the outcomes and the implications of the LCC analysis, including the limitations and uncertainties associated with the results. The report should contain the following:

a) *executive summary* — a brief synopsis of the objectives, results, conclusions and recommendations of the analysis. This summary is intended to provide an overview of the analysis to the decision makers, users and other interested parties;

b) *purpose and scope* — a statement of the analysis objective, product description, including a definition of intended product use environment, operating and support scenarios; assumptions, constraints, and alternative courses of action considered in the analysis, as discussed in **7.2**. (Since this information is included in the LCC analysis plan, this plan may be included in the documentation as reference);

c) *LCC model description* — a summary of the LCC model, including relevant assumptions, a depiction of the LCC breakdown structure, an explanation of the cost elements and the way in which they were estimated, and a description of the way in which cost elements were integrated (including methods of accounting for the time value of money), as discussed in **7.3**;

d) *LCC model analysis* — a presentation of the LCC model results, including the identification of cost drivers, the results of sensitivity analyses, and the output from any other related analysis activities, as discussed in **7.4**;

e) *discussion* — a thorough discussion on and interpretation of the analysis results, including any uncertainties associated with the results, and of any other issues which will assist the decision makers and/or users in understanding and using the results;

f) *conclusions and recommendations* — a presentation of conclusions related to the objectives of the analysis, and a list of recommendations regarding the decisions which are to be based on the analysis results, as well as an identification of any need for further work or revision of the analysis.

7.6 Review of LCC results

A formal review of the analysis process may be required to confirm the correctness and integrity of the results, conclusions and recommendations presented in the report. If such a requirement exists, then the review should be conducted by someone other than the original analysts, to ensure objectivity. The following elements should be addressed:

a) review of the objectives and scope of the analysis to ensure that they have been appropriately stated and interpreted;

b) review of the model (including cost element definitions and assumptions) to ensure that it is adequate for the purpose of the analysis;

c) review of the model evaluation to ensure that the inputs have been accurately established, that the model has been used correctly, that the results (including those of sensitivity analysis) have been adequately evaluated and discussed, and that the objectives of the analysis have been achieved;

d) review of all assumptions made during the analysis process to ensure that they are reasonable, and that they have been adequately documented.

7.7 Analysis update

It is advantageous in many life cycle costing studies to keep the LCC model current so that it can be exercised throughout the life cycle of the product. For example, it may be desirable to update LCC analysis results (which were initially based on preliminary or estimated data) based on more detailed data as it becomes available later in the product life cycle. Maintaining and updating the LCC model may involve modifications to the LCC breakdown structure, changes to cost estimating methods as additional information sources become available, and alterations in assumptions embodied in the model.

The updated LCC analysis should be documented and reviewed to the same extent as the original.

8 Uncertainty and risks

LCC is basically a quantitative measure reflecting an estimate of the cost of acquisition and ownership of a product over its life cycle. As emphasized throughout this standard, the confidence in the results of life cycle cost analysis depends on the availability and use of the relevant information, the assumptions (about the product and future) made in the LCC model, and the input data used in the analysis.

Items such as lack of information at the beginning of the project, introduction of new technology/product, use of optimistic estimates (in order to justify the project), use of unattainable schedules, long research and development projects with unpredictable results, undue optimism/pessimism, etc. all contribute to uncertainty and risk. Elements such as predicted inflation rates, labour, material and overhead costs to be incurred over a long period of time in the future can also cause considerable uncertainty in the results of LCC analysis. Therefore, erroneous conclusions may be drawn and wrong decisions made due to the use of incorrect models, incorrect data, or the omission of some cost significant items.

The uncertainty and risk are further compounded by the fact that many important factors relevant to a decision, may not be quantifiable in terms of costs. Value judgements based on experience should be used to account for such factors. Such value judgements are generally qualitative. In practice, the decision making based on life cycle cost of a product often involves a combination of quantitative and qualitative considerations. The quantitative results provide a baseline reference, whereas qualitative assessments provide reinforcement for further support of the recommendations and decisions.

In order to reduce the risks involved in quantitative assessment, sensitivity analyses should be performed, with a range of potential values considered primarily for parameters of cost drivers and other important variables.The results of such sensitivity studies should be assessed in detail and the possible range of variation in life cycle costing analysis results be provided. The degree of verification of the analysis should be commensurate with the seriousness of the impact of analysis results and the value of the decision. For example, for supporting decisions which are very cost intensive, the life cycle cost analysis may require verification by independent experienced personnel.

It is important that the specific risks involved and the possible range of variation of life cycle cost analysis results are brought to the attention of the decision maker for consideration.

Annex A (informative) Typical cost generating activities

A.1 General

Each phase of the life cycle includes activities that contribute to the costs for that phase. This annex lists some typical activities for each phase for which the costs should be identified. Costs for additional activities should be identified as appropriate at the time the analysis is conducted.

A.2 Typical costs in the product life cycle phases

A.2.1 ***Concept and definition***

Concept and definition costs are attributed to various activities conducted to ensure the feasibility of the product under consideration. These typically include costs for:

a) market research;

b) project management;

c) system concept and design analysis;

d) preparation of a requirement specification of the product.

A.2.2 ***Design and development***

Design and development costs are attributed to meeting the product requirements specification and providing proof of compliance. These typically include costs for:

a) project management;

b) system and design engineering, including reliability, maintainability and environmental protection activities;

c) design documentation;

d) prototype fabrication;

e) software development;

f) testing and evaluation;

g) producibility engineering and planning;

h) vendor selection;

i) demonstration and validation;

j) quality management.

A.2.3 Manufacturing and installation

Manufacturing and installation costs are attributed to making the necessary number of copies of the product, or providing the specified service on a continuous basis. The activities (costs) in this phase are subdivided between those that are non-recurring and those that recur with each product or service provided. These typically include costs for:

a) non-recurring:

1) industrial engineering and operations analysis;

2) construction of facilities;

3) production tooling and test equipment;

4) special support and test equipment;

5) initial spares and repair parts;

6) initial training;

7) documentation;

8) software;

9) testing (qualification testing).

b) recurring:

1) production management and engineering;

2) facility maintenance;

3) fabrication (labour, materials, etc);

4) quality control and inspection;

5) assembly, installation and checkout;

6) packaging, storage, shipping and transportation;

7) ongoing training.

A.2.4 ***Operation and maintenance***

The costs of operation, maintenance, and supply support of systems and support equipment are incurred over the expected life of the system/product. These costs typically include:

a) operation:

1) labour/training;

2) materials and consumables;

3) power;

4) equipment and facilities;

5) engineering modifications;

6) new software releases.

b) maintenance:

1) labour/training;

2) facilities;

3) contractor services;

4) software maintenance.

c) supply:

1) labour/training;

2) spare parts and repair material;

3) warehousing facilities;

4) package, shipping and transportation.

A.2.5 ***Disposal***

This category includes the costs of retiring older versions of the products or its eventual disposal. In some service industries, such as the chemical and nuclear industries, the disposal of products can become a significant cost factor, and may incur substantial penalties.

The costs of a product's disposal typically include costs for:

a) system shutdown;

b) disassembly and removal;

c) recycling or safe disposal.

A.3 Cost elements explanation

Costs for:

— **project management**: The costs for management functions to accomplish overall project objectives during any phase of the life cycle. Examples of these activities are configuration management, quality management, cost/schedule management, data management, contract management, liaison, and product support management.

— **engineering**: Direct labour, materials, overhead, and other direct costs associated with the design and development function, including costs of product engineering and integration, design engineering, and design support.

— **producibility engineering and planning**: Costs associated with the planning and engineering required to ensure the timely and cost effective economic producibility of the product prior to release for production. It includes the efforts required to study the producibility of the product as well as the development of production process. These costs can recur if there is a change in contractor, design, or production process.

— **fabrication**: The direct costs for labour, materials and overheads associated with material acquisition and handling, tooling and test equipment in support of production, fabrication, assembly, integration and test.

— **facilities**: The costs for plant construction, maintenance and modernization, and tooling for production.

— **special support and test equipment**: The costs for standard and unique equipment and tools required to maintain and care for any portion of the product or the entire product.

— **initial training**: Costs incurred to ensure that properly trained personnel are available to operate and maintain the product when it arrives in the field, including the training of instructors.

— **initial spares and repair parts**: The one time costs for items to be used for maintenance purposes to operate and maintain the product during the initial period of product service.

— **consumables**: The costs of material consumed in the operation of the product. Examples include paper, lubricants, fuel, and cleaning materials.

— **contractor services**: The costs for assistance, advice, instruction, training, operation and maintenance provided by separate contract.

blank

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL