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Petroleum, petrochemical and natural gas industries — Life cycle costing

Industries du pétrole et du gaz naturel — Estimation des coûts globaux de production et de traitement

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement)

This first edition cancels and replaces ISO 15663-1:2000, ISO 15663-2:2001 and ISO 15663-3:2001, which have been technically revised. The main changes compared to the previous editions are as follows:

— Clause 3: several new terms, definitions, symbols and abbreviations;

— Clause 4: a new clause has been introduced;

— Clause 5 and Clause 6: new clauses describing life cycle costing management and methodology which have been restructured from previous editions;

— Annex A: contains restructured text from ISO 15663-3:2001;

— Annex C: new annex describing life cycle costing techniques which also includes text from ISO 15663-2:2001;

— Annex B, Annex D, Annex E and Annex F are new annexes, but contain also some elements from the previous editions.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Cost management within the petroleum, petrochemical and natural gas industries is important and will benefit from the adoption of a common and consistent approach to life cycle costing.

Life cycle costing is the systematic consideration of costs and revenues associated with alternative options required to fulfil the objectives of the business. It is an iterative process of planning, estimating and monitoring costs and revenue differences throughout an asset's life. It is used to support the decision-making process by evaluating alternative options and performing trade-off studies. While the largest benefits are typically achieved in the early life cycle phases, it is equally applicable to all life cycle phases and at many levels of detail.

The petroleum, petrochemical and natural gas industries have historically assessed the financial viability of project options based on minimum capital expenditure and achieving project schedule, whilst operating expenditures and lost revenue have received less focus in the decision-making process. This has ignored potentially large cost factors and has in some cases resulted in selecting non-optimal solutions.

Recognizing this situation, life cycle costing is increasingly being applied by a variety of organizations within the industry. All participants in the process — operators, contractors and vendors — can have a substantial impact on the life cycle cost, and it is not until all are involved that the benefits sought from the use of life cycle costing will be realized.

Petroleum, petrochemical and natural gas industries — Life cycle costing

1 Scope

This document specifies requirements for and gives guidance on the application of life cycle costing to create value for the development activities and operations associated with drilling, exploitation, processing and transport of petroleum, petrochemical and natural gas resources. This document covers facilities and associated activities within different business categories (upstream, midstream, downstream and petrochemical).

The life cycle costing process as described in this document is applicable when making decisions between competing options that are differentiated by cost and/or economic value. This document is not concerned with decision-making related to the economic performance of individual options or options differentiated by factors other than cost or economic value.

Guidance is provided on the management methodology and application of life cycle costing in support of decision-making across life cycle phases. The extent of planning and management depends on the magnitude of the costs involved, the potential value that can be created and the life cycle phase. It also provides the means of identifying cost drivers and provides a cost-control framework for these cost drivers, allowing effective cost control and optimization over the entire life of an asset.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 14224:2016, *Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment*

ISO 19008:2016, *Standard cost coding system for oil and gas production and processing facilities*

ISO 20815:2018, *Petroleum, petrochemical and natural gas industries — Production assurance and reliability management*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
abatement cost
cost generated for the removal or reduction of an undesirable item

Note 1 to entry: An item can be several types of avoided emissions, e.g. emissions to air and water, but most commonly used for CO_2 emission reductions. See further information in Clause C.7.

Note 2 to entry: Abatement cost can be both CAPEX and OPEX cost elements.

3.1.2
asset
item, thing or entity that has potential or actual value to an organization

Note 1 to entry: Physical assets usually refer to equipment, inventory and properties owned by the organization. Physical assets are the opposite of intangible assets, which are non-physical assets such as leases, brands, digital assets, licenses, intellectual property rights, reputation or agreements.

Note 2 to entry: A grouping of assets referred to as an asset system (see ISO 55000:2014, 3.2.5) could also be considered as an asset.

[SOURCE: ISO 55000:2014, 3.2.1, modified — Note 1 to entry not included.]

3.1.3
best available techniques
BAT
latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicates the practical suitability of a particular measure for limiting discharges, emissions and waste

[SOURCE: OSPAR Convention:1992, Appendix 1]

3.1.4
break-even price
U_{PV}
price which applied flat to the production sold gives N_{PV}=0

Note 1 to entry: The production can be related to material such as oil, equipment or services. See further information in C.6.3.8.

3.1.5
break-even volume
volume where a stream of revenues and cost balance results in N_{PV}=0

Note 1 to entry: The volume can be related to material such as oil, equipment or services that generates income. See further information in C.6.3.7.

3.1.6
capital efficiency index
CEI
I_{CE}
NPV of a project after tax divided by the absolute value of the NPV of cash flow after tax up to a defined end point

Note 1 to entry: The capital efficiency index illustrates value creation relative to capital exposure. See further information in C.6.3.9.

Note 2 to entry: The absolute value of the net present value of cash flow after tax applies until the point where annual cash flow becomes positive [see Formula (C.8)].

3.1.7
capital expenditure
CAPEX
investment used to purchase, install and commission an asset

Note 1 to entry: See further information regarding estimation of CAPEX in Clause C.2.

3.1.8
code of resource
COR
hierarchical structure of SCCS that classifies all project resources according to the type of contract/resource that is involved in the activity and has an associated set of rates

Note 1 to entry: Specific code of resource structure exist, i.e. SCCS is described in ISO 19008:2016. COR codes can be found at https://standards.iso.org/iso/19008.

[SOURCE: ISO 19008:2016, 2.1]

3.1.9
committed costs
fixed costs that cannot be eliminated or even cut back without having a major effect on profits or on the organization's objectives

3.1.10
constraint
limit imposed externally or internally by the project that rules out the selection of an option if the limit is exceeded

3.1.11
cost breakdown structure
structure related to the methods that an organization employs to record and report costs

Note 1 to entry: Specific cost breakdown structure exists, i.e. SCCS is described in ISO 19008:2016. See https://standards.iso.org/iso/19008.

3.1.12
cost data
cost information associated with a defined cost element

Note 1 to entry: Cost data can be qualitative or quantitative cost information.

3.1.13
cost driver
major cost element which, if changed, will have a major impact on the life cycle cost of an option

3.1.14
cost element
subset at any level of the total cost for a cost breakdown structure

Note 1 to entry: The cost of an object/item, resource, activity or a combination of those.

Note 2 to entry: Specific cost element exists when ISO 19008:2016 is applied, i.e. the term 'cost item' as defined in 3.1.16.

3.1.15
cost issue
cost element which, if changed, will not have a major impact on the life cycle cost of an option

3.1.16
cost item
particular part/level that is coded/classified using the SCCS

[SOURCE: ISO 19008:2016, 2.2]

3.1.17
discount rate
d
rate of return used in determining the net present value of future cash flow

Note 1 to entry: The discount rate is normally given on an annual basis, but can also be given based on another time period, e.g. a monthly or quarterly basis.

Note 2 to entry: See further information in C.6.2.

3.1.18
economic evaluation measure
quantitative measure used to quantify economic characteristics

Note 1 to entry: Economic evaluation measures may apply for the economic comparison where only subsets of costs are needed (e.g. subset of CAPEX, OPEX and revenue factors).

Note 2 to entry: See further information in C.6.3.

3.1.19
fixed cost
cost that does not vary with production volume or with the level of activity

Note 1 to entry: Fixed cost is not necessarily constant throughout all life cycle phases of an asset or an activity.

Note 2 to entry: Both CAPEX and OPEX can have fixed cost items.

3.1.20
initial investment
first investment for a project

Note 1 to entry: Initial investment is a part of the overall CAPEX or the overall CAPEX for the project itself and will depend on the type of project. The timing of initial investment can vary and is important to describe in the LCC calculations in a given project.

3.1.21
internal rate of return
IRR
d_R
rate of return of future net cash flow that gives N_{PV}=0

Note 1 to entry: See further information in C.6.3.4.

3.1.22
item
subject being considered

Note 1 to entry: The item can be an individual part, component, subunit, equipment, system, plant or installation.

[SOURCE: IEC 60050-192:2015, 192-01-01, modified — Note 1 to entry has been adjusted.]

3.1.23
life cycle
series of identifiable stages through which an item goes, from its conception to disposal

Note 1 to entry: The identified stages are defined as *life cycle phases* (3.1.28).

[SOURCE: IEC 60050-192:2015, 192-01-09, modified — Note 1 to entry has been added.]

3.1.24
life cycle cost
LCC
L_{CC}
total cost incurred during the life cycle

Note 1 to entry: LCC is the discounted sum of CAPEX, OPEX and LOSTREV, see C.6.3.3.

Note 2 to entry: Total cost of ownership is sometimes used in preference to LCC when explaining the application of life cycle costing (i.e. the methodology) but it is not used in this document. See further information in 4.2.

[SOURCE: IEC 60050-192:2015, 192-01-10, modified — Notes 1 and 2 to entry have been added.]

3.1.25
life cycle cost analysis
LCC analysis
systematic evaluations and calculations carried out to assess competing options using economic evaluation measures of as part of life cycle costing

Note 1 to entry: The economic evaluation measures are described in C.6.3.

3.1.26
life cycle cost model
LCC model
mathematical relationship between cost elements and life cycle cost differences

Note 1 to entry: The LCC model will contain different economic evaluation measures as described in C.6.3.

3.1.27
life cycle costing
process of evaluating the difference between the life cycle cost of two or more alternative options

Note 1 to entry: Life cycle costing can involve quantitative and/or qualitative assessment.

3.1.28
life cycle phase
discrete stage in the life cycle with a specified purpose

Note 1 to entry: The different life cycle phases are further described in 4.5.

3.1.29
lost revenue
LOSTREV
income loss that occurs when generated income are less than expected due to external or internal factors

Note 1 to entry: When the generated income is related to production, ISO 20815:2018, 3.1.25 defines lost revenue as: Total cost of lost or deferred production due to down time. Production and time loss categories are defined in ISO 20815:2018, Clause G.3.

Note 2 to entry: See further information regarding estimation of lost revenue in Clause C.4, and see also ISO/TS 3250:—[1].

3.1.30
net present value
NPV
N_{PV}
present value that is calculated by discounting the future net cash flow with the required rate of return as the discount rate

Note 1 to entry: In this document, the term net present value is used, even though the industry sometimes uses also the term present value reflecting the same discounted value. See further information in C.6.3.2.

3.1.31
operating expenditure
OPEX
expenses used for operation and maintenance, including associated costs such as logistics and spares

Note 1 to entry: See further information regarding estimation of OPEX in Clause C.3.

3.1.32
payback period
Y_{PB}
period after which the initial investment has been paid back by the accumulated net revenue counted from the first income

Note 1 to entry: The payback period is also sometimes called pay-out time. See further information in C.6.3.6.

Note 2 to entry: When the payback period is calculated, it is important to state whether it is based on the summation of nominal values or based on discounted values where the latter can lead to a somewhat longer payback period.

3.1.33
physical breakdown structure
PBS
hierarchical structure of SCCS that defines the types of physical asset components of field installations being delivered by the activity

Note 1 to entry: Specific physical breakdown structure exists, i.e. SCCS is described in ISO 19008:2016. PBS codes can be found at https://standards.iso.org/iso/19008.

[SOURCE: ISO 19008:2016, 2.6, modified — Note 1 to entry has been added.]

3.1.34
production availability
ratio of production to planned production, or any other reference level, over a specified period of time

Note 1 to entry: This measure is used in conjunction with analysis of delimited systems without compensating elements such as substitution from other producers and downstream buffer storage. Battery limits need to be defined in each case.

Note 2 to entry: See further information in ISO 20815:2018.

[SOURCE: ISO 20815:2018, 3.1.46, modified — Notes 1, 3, 4 and 5 to entry have not been included, new Note 2 to entry has been added.]

3.1.35
profitability index
PI
I_P
ratio of NPV of the project divided by the discounted CAPEX

Note 1 to entry: See further information in C.6.3.5.

3.1.36
required rate of return
discount rate requirement by the decision-maker for minimum profit for the investment project

3.1.37
revenue
income generated from normal business activities

3.1.38
revenue gain
generated income that is higher than expected due to external or internal factors

3.1.39
risk
combination of the probability of an event and the consequences of the event

Note 1 to entry: This definition is based on ISO/IEC Guide 51:2014, 3.9 that defines risk as combination of the probability of occurrence of harm and the severity of that harm, where the probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event and the possibility to avoid or limit the harm. "Harm" has been replaced by "event" in the definition to cope with production assurance purpose. It is also similar to the definition of the "level of risk" given in ISO Guide 73:2009, 3.6.1.8 (i.e. "combination of consequences and their likelihood").

[SOURCE: ISO 20815:2018, 3.1.54, modified — Note 2 to entry not included.]

3.1.40
standard activity breakdown structure
SAB
hierarchical structure of SCCS that defines the type of activity that is being performed

Note 1 to entry: Specific standard activity breakdown structure exists, i.e. SCCS is described in ISO 19008:2016. SAB codes can be found at https://standards.iso.org/iso/19008.

[SOURCE: ISO 19008:2016, 2.8, modified — Note 1 to entry has been added.]

3.1.41
standard cost coding system
SCCS
standard system for classification and coding cost estimates, monitoring and final quantities and cost data

Note 1 to entry: The SCCS code comprises three individual hierarchical coding structures named PBS, SAB and COR, each based upon a different aspect/facet of the scope of work.

Note 2 to entry: In this document, SCCS means the use of ISO 19008:2016.

[SOURCE: ISO 19008:2016, 2.7, modified — Note 2 to entry has been added.]

3.1.42
sustainability
state of the global system, including environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their own needs

[SOURCE: ISO Guide 82:2019, 3.1, modified — Notes to entry not included.]

3.1.43
uncertainty
<of a quantity> inability to determine accurately what is or will be the true value of a quantity

Note 1 to entry: Uncertainty can have different meanings. It can be used as a measure of variability within a population, which is a type of uncertainty often referred to as stochastic (or aleatory) uncertainty. Uncertainty can also have a subjective meaning (epistemic uncertainties).

Note 2 to entry: Uncertainty of input data is particularly important for life cycle costing. See further information in 6.4.4 and D.5.

Note 3 to entry: Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequences, or likelihood.

[SOURCE: ISO 14224:2016, 3.95, modified — Note 1 to entry has been adjusted, and Notes 2 and 3 to entry have been added.]

3.1.44
variability
variations in performance measures for different time periods under defined framework conditions

[SOURCE: ISO 20815:2018, 3.1.62, modified — Note 1 to entry not included.]

3.1.45
weighted average cost of capital
WACC
average after-tax cost of a company's various capital sources, including stocks and interest-bearing debt

Note 1 to entry: WACC is the average rate a company expects to pay to finance its assets. See further information in C.6.3.2.

3.2 Abbreviated terms

DRILLEX	drilling expenditures
EPC	engineering procurement and construction
EPCI	engineering procurement construction and installation
EPIC	engineering procurement installation and commissioning
FEED	front-end engineering design
FID	final investment decision
FPSO	floating production storage and offloading
HSE	health safety and environment
LCCMP	life cycle costing management plan
LNG	liquefied natural gas
MU	monetary units

4 Application

4.1 Users of this document

This document is intended for users responsible or involved in life cycle costing and associated activities such as:

— Installation/plant/facility: Operating facility, e.g. HSE, engineering, construction, installation, operation and maintenance personnel.

— Operator/owner/company: Project management and control, technology development, technology qualification, concept and system design, HSE, integrity management, maintenance management, production assurance, etc.

— Contractor: Main contractor for engineering, procurement, construction, drilling, installation, operation, maintenance services, etc.

— Vendor/manufacturer/supplier: Technology development, technology qualification, system design to ensure product quality and improvements, etc.

— Authority/regulatory body: Regulatory requirements that can refer to this document to enhance HSE, production availability, system availability, operability, maintenance and resource utilization.

— Consultant: Consultancy services for supporting system design, production assurance and reliability management, technical safety, etc.

— Industry: Any other user involved in life cycle costing activities in the industry.

4.2 Framework conditions

The objective associated with life cycle costing is to provide decision support for selecting between alternative options (e.g. technical and operational items), which are aligned with overall corporate business objectives. Figure 1 illustrates that this is different from company economics and project economics.

The following applies as part of defining the framework:

— when establishing a consistent cost breakdown structure for the competing options, ISO 19008:2016, related to cost coding, shall be evaluated for use (see 6.3.1 and Annex C);

— when establishing qualified data input and calculation of operating expenditures, revenue and lost revenue, ISO 14224:2016 and ISO 20815:2018, related to reliability data, production assurance and reliability management, shall be used (see Annex C);

— consideration should be given to quality management, for which ISO 9000:2015, ISO 9001:2015 or ISO 29001:2020 can be used;

— consideration can be given to social responsibility, for which ISO 26000:2010 can be used.

The LCC model is the quantitative model used when comparing competing options. This LCC model can be different from economic models used by the operator for other purposes. In such specific cases, explanation of essential differences should be given.

In the majority of cases, a spreadsheet model represents the most cost efficient and flexible solution for an LCC model for comparison of options (see 6.4.2). The LCC model developed should be simple enough to be transparent to the user, but accurate enough to represent the difference between options.

Life cycle cost is defined as the total cost incurred during the life cycle. As indicated in Figure 1, life cycle cost is derived numerically. This numerical output is sometimes referred to as the total cost of ownership rather than LCC, to provide distinction between life cycle costing as an activity and LCC as an output. While LCC and total cost of ownership can be considered numerically equivalent, LCC is used in this document. Total cost of ownership is not used to prevent possible confusion of with so-called “ownership cost”, which can exclude cost elements and cost drivers that are included in LCC. Similarly, ownership cost may include costs relating to project economics (e.g. depreciation) that do not form part of LCC.

IEC 60300-3-3:2017 provides a general introduction to the concept of life cycle costing and covers all industry applications.

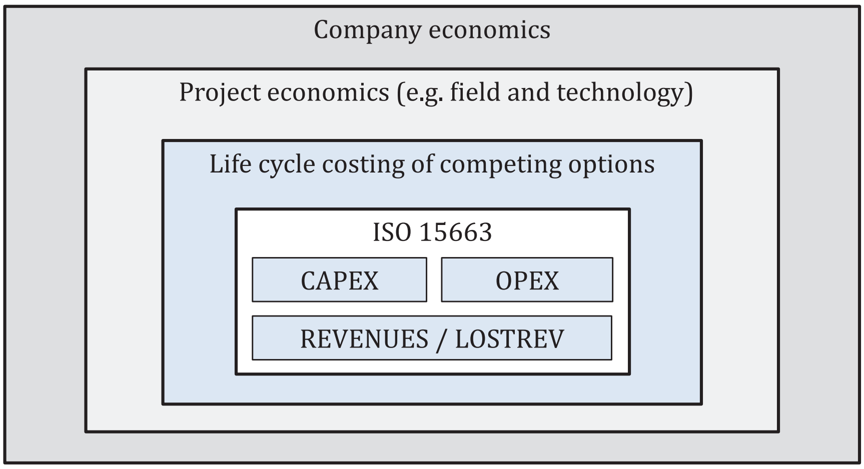


Figure 1 — Framework conditions for life cycle costing

4.3 Limitations

4.3.1 General

This document specifies requirements and provides guidance for application and implementation for undertaking life cycle costing. Some limitations are described below.

— This document focuses on life cycle cost comparison between competing options for a subject matter (see also 4.6). This document is not intended for the entire project economy evaluation of field development projects or investment appraisals, for which all cost issues need to be covered. Comparative life cycle costing will include only the relevant cost elements. Thus, this document also provides guidance for use in the selection of the relevant cost elements to ensure cost-effective life cycle costing.

— The detailed analyses required to accurately predict life cycle cost will, in many cases, require input data and information derived from other efforts, such as reliability modelling, maintenance analysis, logistic, material and spares studies or other techniques that help develop individual cost element estimates. This document will not address in detail how to apply these specialist techniques. These techniques are not unique to life cycle cost analysis and are described in other relevant International Standards, such as ISO 14224:2016 and ISO 20815:2018. See also Annex C.

— This document does provide typical life cycle costing calculation methods and describes the common and best practice analytical concepts. Potential users are made aware that companies will often have specific requirements in areas such as the treatment of cash flow, discounting assumptions, views on uncertainty and risk management, guidelines on margin and their own decision support metrics and economic decision-making criteria. This document enables users to conform with life cycle costing requirements or reveal nonconformance and possibly (as needed) describe company specific issues used in this context.

— Capital projects may require extensive value engineering studies to support incremental investments. The sensitivity analyses usually associated with value engineering can be varied and diverse. This document provides case specific examples, but it is important to understand the basic concepts and tailor them to particular study requirements as required.

— Contractual relationships between operators, equipment suppliers and engineering contractors can be complex and difficult to manage consistently. This document identifies common contractual considerations, some potential pitfalls and recommendations for successful outcomes when collaborating with third parties. It cannot be exhaustive in terms of covering all potential scenarios, relationships or contracting plans. The user should understand the basic life cycle costing concepts prior to starting a life cycle costing study which involves third parties.

- A more specific consideration between different companies is joint venture agreements, usually between oil and gas operating companies. In these situations, individual company economic considerations and investment decision criteria can be different between partners. For example, the treatment of cash flow can be different between companies.
- It is recognized that making a decision on any option is not always driven by cost or economic value considerations. Different business drivers or objectives can determine the decision, even if some of these drivers could not be quantified in equivalent cost and/or benefits. For example, the opportunity to use and test new technology, HSE targets, sustainability, climate change impact, energy efficiency, risk mitigation or opportunity exploitation, local or technical constraints, budget limitations or cost exposure, value of reputation, market context or contractual schemes, could drive or contribute to determining the final decision between options.
- This document provides recommendations on typical roles and competency expectations for staff involved in life cycle costing which are not intended to be considered requirements.

4.3.2 HSE considerations

Health, safety and environmental constraints prevail over cost when evaluating competing options. HSE considerations are therefore important when scoping life cycle costing (see 6.2) to assess whether competing options conform with the minimum set of HSE requirements. The recommended option (see 6.5) shall always conform to these HSE requirements. The degree of technical, operational, organizational or human HSE related issues amongst competing options can vary or is only important for some of the competing options. The choice of life cycle costing subject matters should also have a management focus for enhancing HSE level (see 4.6).

Depending on the life cycle costing subject matter and associated competing options, how and when to reflect HSE can vary when quantifying the main elements of life cycle costing, i.e. CAPEX, OPEX and revenue factors (REVENUES or LOSTREV). The LCC analysis can then be difficult and can form an important condition or uncertainty for final decision-making, where decision criteria (e.g. regulatory safety requirements and company HSE targets) will also apply. Increased CAPEX to enhance HSE level can be preferred over the higher cost (OPEX and LOSTREV) arising from the failure consequence of unacceptable HSE level (see e.g. ISO 14224:2016, Table C.2). Increased OPEX and LOSTREV due to potential hazards and accidental events may be explicitly formulated to reveal this, to support decision-making. The HSE implications during the life cycle phases shall also be considered when using life cycle costing for selecting between competing options. Further information regarding environmental aspects is provided in Clause C.7.

HSE considerations for the purpose of life cycle costing can require support from risk management, risk analysts and technical HSE personnel (see e.g. ISO 20815:2018, Clauses C.2, F.4, and I.20, and ISO 31000:2018). The balance between HSE and cost should also be considered when the life cycle costing subject matter is comparison of different preventive maintenance options, e.g. optimizing test interval for safety critical equipment as defined in ISO 14224:2016, 3.84 (see also ISO 20815:2018, Clause I.16, and ISO/TR 12489:2013).

4.3.3 Sustainability and climate change considerations

Sustainability and climate change considerations are part of the life cycle costing activities, not only in conjunction with associated costs, but also in terms of expected performances and benefits of each option, in support to the decision-making process. This can be related to mitigation and adaptation measures.

The carbon footprint of a product (as defined in ISO Guide 84:2020, 3.1.32) can vary between the competing options and over the life cycle. Depending on the business objectives and authority requirements, the LCC analysis should include the relevant factors.

This document also has economic evaluation measures that cover abatement cost (see Clause C.7). This can lead to a higher LCC of a selected (recommended) option that achieves better carbon footprint performances than a less expensive option.

Corporate and authority requirements or targets can affect the degree the LCC analysis alone forms basis of decision-making, or whether the life cycle costing provides support to more overall decision-making addressing aspects outside the scope of this document, such as sustainable procurement (see ISO Guide 82:2019 and ISO 20400:2017).

IOGP report 437[20] can also be considered when evaluating different competing options related to sustainability.

4.4 Benefits of life cycle costing

Applying life cycle costing has several benefits. Experience has demonstrated that:

— for the operator, life cycle costing integrates readily with existing appraisal techniques, can quantify and optimize costs and revenues over the total life of a field development, thereby reducing uncertainty;

— for the contractor, life cycle costing provides techniques to support the extension of his role into areas such as maintenance management, integrated service provision, engineering services contracts and life cycle costing consultancy;

— for the vendor, life cycle costing provides a common and consistent basis for demonstrating improved service and quality, thereby extending their role beyond technical conformance and lowest price.

Figure 2 illustrates the degree of participants involvement on the level of detail and the life cycle phase. This allows them to easily recognize where the maximum value can be reached in applying life cycle costing in their work processes.

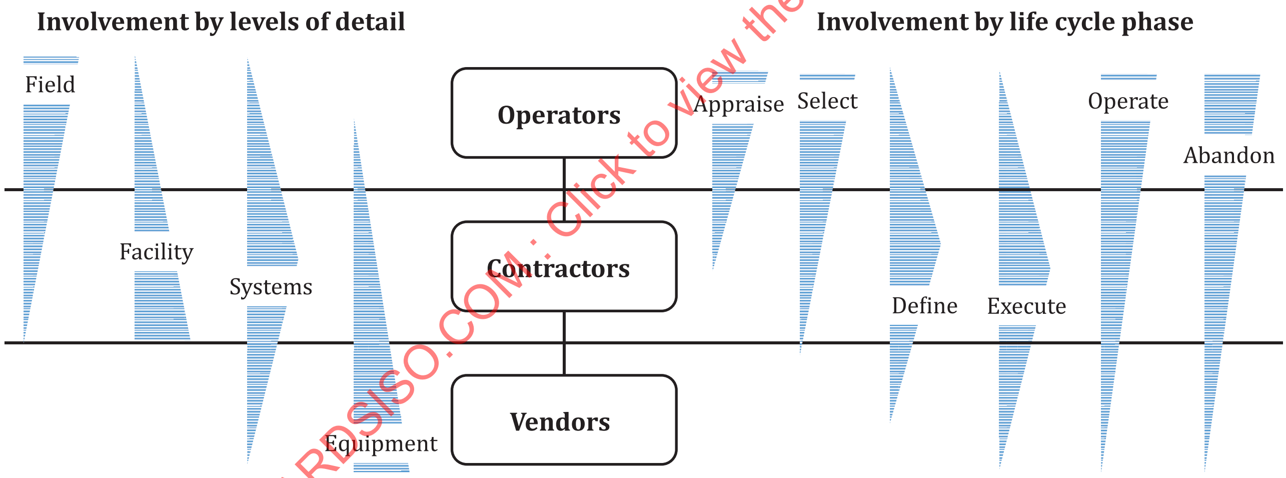


Figure 2 — The role of participants with respect to level of detail and life cycle phase

The systematic application of life cycle costing in a project development context will include any or all of the following benefits:

A. Strategic alignment: All engineering decisions being made by considering the consequences on OPEX and their effect on the revenue profile, in accordance with the corporate objectives of adding value on investments.

B. Improved framework for performance contracts and life cycle costing: Enhancing the overall quality level of materials and services in the supply industry through the development of performance contracts amongst operators, contractors and vendors with complementary metrics besides CAPEX, e.g. operating phase metrics (systems availability guarantee and risk-sharing clauses).

C. Improved decision criteria for selecting a profitable option: Supporting the decision-making process with the establishment of predefined criteria to rank and analyse the options with respect to their added value.

D. Increased operating predictability: To perform life cycle costing assessments, it is necessary that operating expenditure elements are identified at an early stage. In this sense, operating experience plays an important role in preventing cost underestimation and cost overruns. Technical operating experience is also a valuable resource that can be introduced early in a project development to select and evaluate options to be compared.

E. Targeted planning of the life cycle costing activities: An integrated planning for all stages of development ensures that the resources required for life cycle costing assessments will be available in an adequate time to provide the necessary inputs to the task of comparing options for a process function and consider the effects of these decisions on other process functions. The use of an LCC model enables the identification, targeting and reduction of cost drivers. Then, a sensitivity analysis may indicate critical functions that will become targets for research and development, technology transfer and a focus for management effort.

F. Long-term economical perspective: The quantitative approach to life cycle costing provides an early diagnosis of the project's economic performance over time. This feature allows a common basis to compare not only the functions within a project, but also an integrated economical approach to the business portfolio.

4.5 Life cycle costing within the life cycle phases

The primary purpose of life cycle costing is to assist the delivery of the highest possible added value, i.e. profit, within a field development or project. It achieves this by extending profit improvement opportunities through a process of progressive optimization. The greatest benefit is realized when life cycle costing is integrated across the entire life cycle. The different life cycle phases are defined in Table 1.

Table 1 — Life cycle phases (for asset/project) — for facility owner/operating company

Id.	Life cycle phase	Phase outcome/ delivery	Phase outcome/ delivery (for a project in existing asset)
0	Explore	Identified business opportunities	Identified business opportunities
1	Appraise	Feasible installation concept(s)	Feasible solution(s)
2	Select	A selected (preferred) installation concept	A selected (preferred) solution
3	Define	A defined (matured) installation concept for final investment decision (FID)	A defined (matured) solution for final investment decision (FID)
4	Execute	The installation is ready to start production/operation	The solution has been installed and is ready to start production/operation

NOTE 1 Facility owner/operating company can be oil company, rig owner, etc.

NOTE 2 The life cycle phases are defined for the purpose of this document and further sub-division is given in Figure B.1.

Table 1 *(continued)*

Id.	Life cycle phase	Phase outcome/ delivery	Phase outcome/ delivery (for a project in existing asset)
5	Operate	End of installation operating life	End of (modified) installation operating life
6	Abandon	The facility has been removed and disposed	The facility has been removed and disposed
NOTE 1 Facility owner/operating company can be oil company, rig owner, etc.			
NOTE 2 The life cycle phases are defined for the purpose of this document and further sub-division is given in Figure B.1.			

The typical scope and objectives of life cycle costing activities for each life cycle phase are as follows:

— Explore (e.g. identification of business opportunities). Life cycle costing activities for this phase are business opportunities, ranked utilizing high-level life cycle costing considerations.

— Appraise (e.g. identification and assessment of feasible concepts). The scope of this phase normally includes gross comparisons of the major technical options. The focus is on the major cost and revenue trade-offs with adequate levels of detail.

— Select (e.g. concept development and concept selection). In this phase, alternative technical and operational solutions are normally examined and compared, aiming at selecting a preferred concept. Processing and delivery are considered as well as procurement options (lease or buy) and the options for operation and support.

— Define (e.g. conceptual/outline system design and front-end engineering design). Life cycle costing activities in this phase typically include the identification and examination of the technical options for facilities, processes and delivery leading to a defined (matured) preferred concept or technical solution for FID.

— Execute (e.g. engineering, procurement, fabrication, testing, installation and commissioning). The scope of work will include system and equipment optimization within constraints defined during the life cycle phase 'Define', and also support change control and project managers assessing the impact of concessions the relevant economic evaluation measures.

— Operate (e.g. operation and maintenance, modification and life extension). For normal operations and maintenance, the work at this stage supports the optimization of a wide range of facility operations and support. Life cycle costing is also applicable when assessing modifications to the facility or the potential to extend operations beyond the original design life. If major modifications are involved, this requires reference to the issues considered above under the 'Select', 'Define' and 'Execute' life cycle phases.

— Abandon (e.g. disposal and decommissioning). The work in this phase will typically include examination of when and how to decommission and dispose of all or part of the asset.

See Annex B for further details and guidance on life cycle costing activities for each of the life cycle phases.

Time to market, from concept to conclusion of commissioning, is shortened due to business and economic drivers. Contractor and vendor selection are performed early in the life cycle, with increased emphasis on their capability and performance. Contracting strategies evolve in parallel, with a variety of partnering, alliance and framework agreements being established.

From a vendors' perspective, it is possible to add most of their value in the systems design since they are often involved in the early life cycle phases such as the life cycle phase 'Define'. On the other hand, contractors can experience benefits coming from life cycle costing principles in all life cycle phases. For operators, it is important that a life cycle costing methodology be established in order to capture value especially in conceptual, operational and abandonment phases.

4.6 Life cycle costing subject matters

Life cycle costing is a methodology used in the oil and gas industry to determine the most cost-effective offer between alternative competing options that satisfy and improve technical, operational, health, safety, environmental and regulatory requirements. Decision-making is made throughout the life cycle of an oil and gas asset starting at the life cycle phase 'Appraise' through the 'Select', 'Define', 'Execute' and 'Operate' life cycle phases and even finally in the life cycle phase 'Abandon'.

The greatest opportunity of influencing the life cycle cost of an asset and its ultimate profitability is the 'Select' and 'Define' life cycle phases of a project (see Figure 3). Decisions and selections made in these two phases have repercussions in the later phases of a project, as the ability to make subsequent changes diminishes and the cost of change increase significantly. Hence, the importance of making the right decision in the 'Select' and 'Define' life cycle phases of a project.

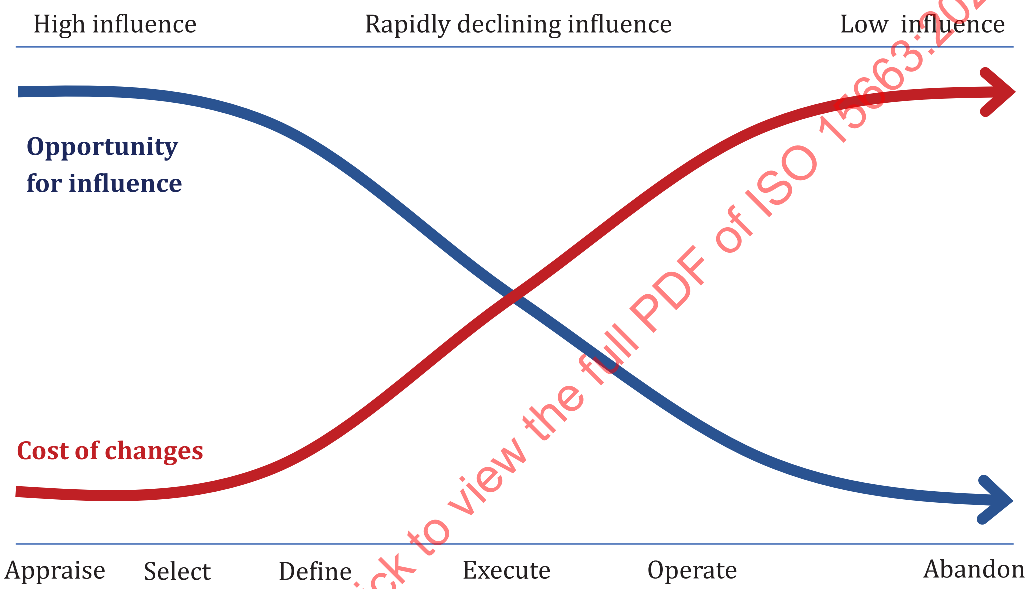


Figure 3 — Opportunity for influence vs cost of change

Two primary life cycle costing decisions taken in the life cycle phase 'Select' for a project are:

— facility concept selection;

— process concept selection.

Examples include topside vs. subsea development, topside vs. subsea compression and full processing offshore vs. onshore treatment.

Having defined the concept to be developed, subsequent life cycle cost decisions to be made during subsequent life cycle phases may include:

— system concept and sizing;

— equipment type, configuration, vendor selection;

— layout and equipment location;

— future facility modifications;

— health, safety and environment;

— project execution strategy;

— maintenance and operation strategies;

— manning strategy and levels;

— logistic support strategy;

— spares and support strategies;

— decommissioning planning and strategy;

— reuse and/or disposal.

The list above illustrates typical life cycle costing subject matters, and that they vary between life cycle phases. Identified life cycle costing subject matters are subject to the life cycle costing methodology as described in Clause 6.

4.7 Technology development

Decisions to develop and deploy new technologies in capital projects or during operations in support of performance improvements are partly based on consideration of life cycle economics. Life cycle cost analysis can be used as the basis for comparing alternative technology solutions or as input into the assessment of larger systems also subject to critical economic evaluations.

Comparing alternatives which include new technologies should consider the risks and uncertainties associated with the ability to qualify to specification and on schedule. These development factors are fundamental for relating expenditures and revenues. They require careful breakdown of cost related elements and rigorous data analysis and modelling to be carried out. Life cycle costing can be used to help subdivide technology development and deployment elements and assist with incremental economic comparisons of alternatives.

A characteristic of new technology projects is the challenge in handling uncertainties associated with input data, analysis results and ranking of alternatives, but analysis methods and techniques can be applied to reflect and describe the ranges of uncertainty. Depending on the complexity of the uncertainties, life cycle costing methodology can employ advanced simulation and detailed probabilistic assessments to critical areas requiring further attention.

5 Management of life cycle costing

5.1 General

Management of life cycle costing is important to add value and ensure cost-efficiency.

Clause 4 provides background and framework conditions for life cycle costing required to evaluate differences between costs and revenues when considering alternative competing options. Understanding the detailed analyses required to accurately predict relevant economic evaluation measures (e.g. life cycle cost) and to evaluate complex trade-offs between uncertain and variable revenues and associated cost elements requires disciplined and critical examination and structured (decision support) management.

Life cycle costing as a capability area within organizations should be developed in terms of ability to consistently and reliably predict the total costs and revenues for the life cycle of an asset, with respect to competing options. The capabilities are required for application in both capital project environments and where incremental investments may be considered to improve HSE, production availability, and equipment and system performance during the life cycle phase ‘Operate’. Life cycle costing also provides better decision support to assess the potential benefits and value of developing and deploying new technologies.

Regardless of whether life cycle costing is used in capital projects, performance improvement initiatives or the development and deployment of new technologies, organizations leveraging the techniques should use it to help confirm proposed solutions are commercially attractive and that results are developed in a manner that can be presented alongside or integrated with other assessments of indirect and non-economic benefits.

Because analysis supports significant investment considerations, it is crucial that management of life cycle costing capability aims for levels that are sufficiently developed and recognized in their role supporting high quality decision-making. It further aims to ensure that the economic objectives of projects are properly stated to allow effective life cycle costing to be carried out and that roles and responsibilities of those involved in life cycle costing are clearly defined. Management of life cycle costing also covers strategy and planning requirements, contractual considerations and systems to evaluate effectiveness through formal review and feedback activities. It also provides frameworks to ensure that life cycle costing competencies and knowledge (i.e. standardized methods and application of life cycle costing methodology) are obtained and practiced in a quality-oriented manner for the users of this document.

This clause covers typical life cycle costing objectives, roles and responsibilities. It describes strategy, planning and contractual considerations, the assessment of life cycle costing effectiveness and minimum training and competency expectations. It has been written principally from the perspective of the operating companies who require high quality LCC analysis and evaluation to meet their end user needs, and also because they are more likely to have life cycle costing professionals within their organizations. It is recognized that engineering companies, equipment vendors and other entities involved in the project and operations value-chain have important roles in the planning and execution of effective LCC analysis.

Life cycle costing activities have an interdisciplinary character that requires expertise in economics, accounting, engineering and operations research and data analysis. Therefore, implementing a life cycle costing system involves management and can involve (depending on the organization) utilizing a team that can share competencies and resources in an effective and efficient manner to perform LCC analyses that have quality and sufficient accuracy.

An organization shall include elements of life cycle costing requirements in a management system. These elements can consist of:

— developing capability and competencies in life cycle costing techniques and best practices that adhere to this document;

— identification of high-level subject matters for which key life cycle costing activities and organizational roles need to be incorporated.

— inclusion of the selected life cycle costing considerations in project and operations strategies and planning cycles.

— defining the need for a project to establish roles, resources and competency requirements for carrying out life cycle costing activities;

— inclusion of life cycle costing requirements in contracting strategies reflecting customer-client relationship(s);

— incorporating life cycle costing considerations as a decision support element in the selected commercial decisions associated with the acquisition of equipment and/or services.

This document recommends that the listed processes and activities are initiated only if they can be considered to add value.

5.2 Objectives for management of life cycle costing

The main objectives for management of life cycle costing are:

— to achieve agreement at a management level on asset objectives and how life cycle costing is linked to these objectives;

— to communicate these objectives and the role of life cycle costing throughout the organization;

— to define the purpose of life cycle costing prior to any activities taking place.

Other underlying objectives are:

— describing the application of the principles of life cycle costing to support projects and operations to achieve business planning objectives;

— providing direction on key life cycle costing methods used in investment evaluations and decisions through detailed description of the techniques and presentation of case-specific examples;

— providing additional references on the latest best practices and sources of the related information needed to carry out complex life cycle costing analysis;

— helping to communicate the role that life cycle costing has in both capital project and operational phases environments;

— identifying typical roles and responsibilities of analysts, decision-makers and others providing inputs to life cycle costing activities;

— providing guidance on planning, executing and assuring life cycle costing including contractual considerations and expected training and competence requirements.

5.3 Roles and responsibilities

The organization shall determine and provide the persons necessary for effective execution of the life cycle costing function, and this should be described in the life cycle costing management plan (see 5.4 and A.1.3).

An individual or organizational unit should be assigned the role of life cycle costing coordination (e.g. through a life cycle costing coordinator) to undertake the following tasks:

a) develop and plan the life cycle costing strategy;

b) develop life cycle costing project procedures;

c) facilitate and coordinate study activities;

d) organize training of all key personnel.

The persons involved in life cycle costing may change depending on the life cycle costing subject matter portfolio and the life cycle phase of the asset.

Life cycle costing coordination can benefit from having a life cycle costing coordinator for large programmes having many subject matters. The life cycle costing coordinator can be a person or group already part of the project group.

Organizational units or assigned persons having responsibility for performing life cycle costing shall:

a) understand the life cycle costing methodology;

b) be able to tailor the life cycle costing activities to the needs of the project;

c) provide the focus for identification and evaluation of alternative options;

d) ensure that issues that influence the life cycle costing and the relevant economic evaluation measures of the project are considered, and that potential trade-offs between cost and revenue remain a key topic;

e) resolve problems identified during life cycle costing within required time and budgets;

f) communicate the results to others — it is only by doing this that decisions can be influenced.

In order for the full benefits of life cycle costing to be achieved, the effect on the overall value of an asset over its lifetime should be considered when making all major decisions. Life cycle costing is therefore the responsibility of all individuals who take these decisions.

5.4 Strategy and planning – life cycle costing management plan

5.4.1 Life cycle costing management plan

The strategy and policy for life cycle costing shall be defined, together with the means of evaluating whether business objectives can be achieved better by use of life cycle costing as described in this document.

Plan(s) for managing life cycle costing in specific projects shall be prepared outlining all defined life cycle costing activities. The planning output should be included in an LCCMP or included in another planning document. The planning output should be updated for each life cycle phase, including the life cycle phase "Operate", to accumulate asset specific know-how for cost-effective future decision support.

Life cycle costing activities (e.g. ranging from coarse qualitative cost/benefit evaluations to detailed quantitative studies), as defined in LCCMP should be carried out where benefits in terms of increased asset value can be realized by selecting the best option between competing alternatives. The options to be studied should be selected on a systematic basis by considering the major contributions to capital and operating expenditures and revenue impact (i.e. lost revenue and revenue gain). The content of a typical LCCMP is provided in A.1.2.

5.4.2 Life cycle costing process

The life cycle costing methodology consists of four steps. These four steps are illustrated in Figure 4 and are further described in Clause 6. Any life cycle costing activity shall follow these four steps. If alternative steps are defined during the planning process, then these shall be justified.

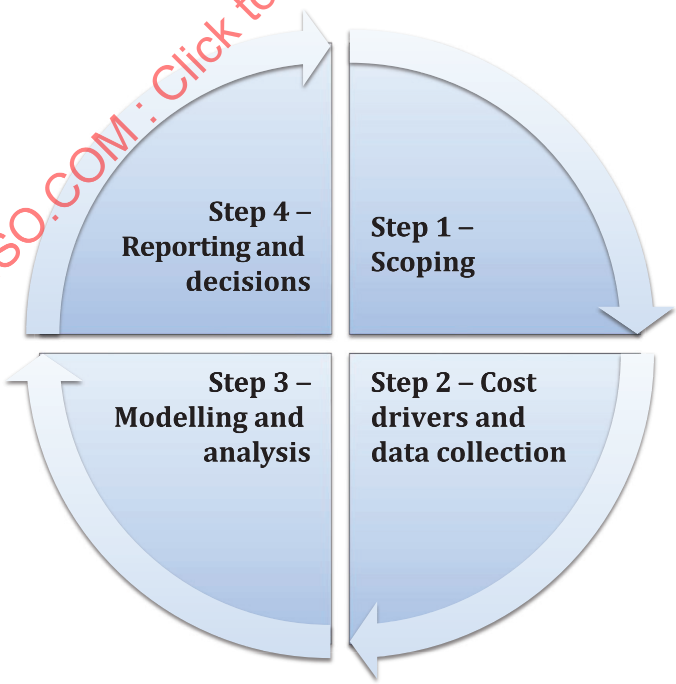


Figure 4 — The life cycle costing process

The life cycle costing process applies to all identified life cycle costing subject matters (see 4.6).

The overall process is iterative and may be repeated a number of times in a project. The reason for the repetition will typically be dependent on the outcome of the previous iteration. This can result in the need to assess further technical or operational options, challenge initial assumptions or constraints, or respond to changes elsewhere within the LCCMP.

Iteration should be carried out for all major cost drivers and areas where there is potential for creating value. This should be agreed on a project basis. The iteration may be deferred to the next life cycle phase (see 4.6) when this does not lead to committed costs at the next stage.

Because the process is iterative, it should be integrated into the overall project planning so that the outcome of each iteration can coincide with the decision points in the project. The LCCMP also provides the means by which the interaction with other team members can be defined and established.

When planning the work, the range of options identified at the start of work do not necessarily represent the full range of options. This is because the opportunities, and hence the options, do not become apparent until at least one iteration has been completed.

The life cycle costing process contains a large number of tasks. Not all tasks are needed in every iteration and the level of detail considered in each task will vary according to the needs of the study. The work undertaken and the LCCMP shall be tailored to meet the objectives and constraints defined.

The output from the process shall be retained as documented information.

The value of a well-documented process will become apparent when the requirements for assessment and internal consistency are considered, the results are produced, and further iterations take place.

5.5 Contractual strategies

The incorporation of life cycle costing within a contractual framework is important. This can be achieved by the following two approaches:

— A low-risk approach where life cycle costing is progressively introduced by making some part of the payment related to life cycle costing performance.

— A high-risk approach where life cycle costing is introduced immediately as the basis for establishing a contract. This approach requires significant levels of life cycle costing awareness, well-established data sources and expertise from the participants in the process.

A typical example of the first approach is the post-market service contract that a vendor or contractor could be asked to provide for the maintenance and operation of their equipment.

Typical examples of the second approach are the leased floater contracts in which the treatment and storage floaters for oil, gas, LNG, etc. are built, owned and operated by the contractor and the operator pays a daily fee.

The implementation of life cycle costing in a contractual context shall be considered within the following activities:

a) prequalification, both for contractors and vendors;

b) development of the tender documentation, which sets the requirements for the bid responses and subsequent evaluation;

c) contract award and post-contract performance monitoring.

Further description and guidance on contractual issues related to life cycle costing are provided in A.1.4.

5.6 Assessment and feedback

An asset owner may require evidence that all of the decisions and assumptions made at all stages of the life cycle costing methodology meet the needs of the business. This requires that an assessment method is established to meet the needs for internal audit (consistency checks) and external audit (feedback to others). Annex F provides guidance on assessment and feedback.

5.7 Training and competence

Training in life cycle costing can be required to ensure consistency of approach. The life cycle costing training needs of a project will vary with the size and complexity of the project and with the contract terms and conditions. The life cycle costing training needs should be considered in conjunction with life cycle costing planning (see A.1.2) and coordination (see A.1.3).

6 Methodology

6.1 General

The methodology for the life cycle costing activities is based on the 4-step process elements shown in Figure 4. The tasks underlying the methodology detailed in this clause are illustrated in Figure 5.

The 4-step methodology applies for all identified life cycle costing subject matters. In these steps several tasks are listed which will assist the user in assessing the scope and scale of the work. These are described in 6.2 to 6.5. The life cycle costing techniques shall be used in accordance with Annex C.

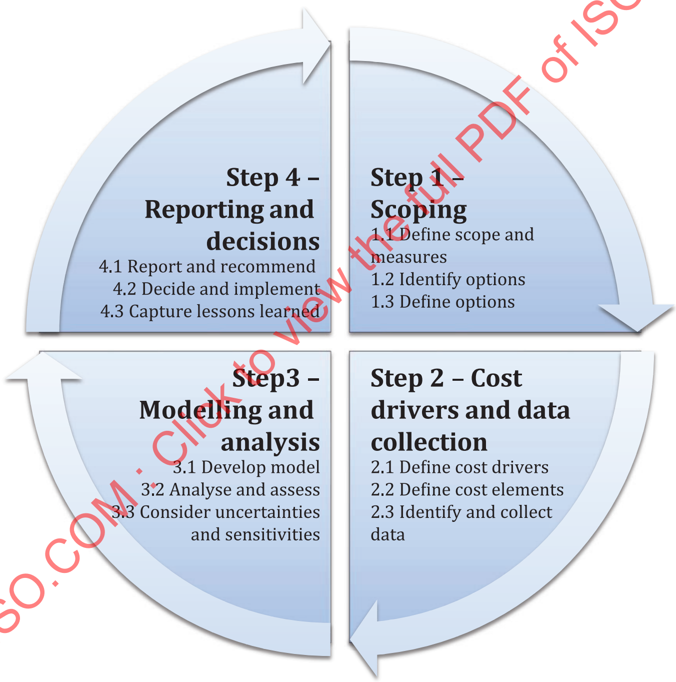


Figure 5 — Sub-division of the life cycle costing methodology

The contribution of life cycle costing to a project is important as any other support functions, such as design, HSE, reliability management or engineering. Each of these functions provides its own unique perspective on the problem and each examines some aspects of performance. Life cycle costing adds a long-term economic perspective and provides the means to compare alternative options on a common economical basis. Life cycle costing cannot be carried out in isolation and should interact with the other functions as part of the team approach.

6.2 Step 1 — Scoping

6.2.1 Objective

Step 1 is the starting point for the life cycle costing process. This step is critical for the successful implementation of life cycle costing in any project, i.e. identification of the important competing options for the relevant life cycle costing subject matters. The objective of this step is to develop a fundamental understanding of the issues, relationships, assumptions and requirement underpinning the work. This can only be achieved by discussion with asset owners and members of the project team. Results of such interaction will enable improved decision support and added business value by the selection option.

From a planning perspective, consideration of the tasks in this step will provide the basis for identifying the scope of the work and the resources required. This should be described in the project planning and/or in a dedicated LCCMP (see A.1.2).

Step 1 is always required, both initially and in subsequent iterations. In later iterations its scope can be reduced to a check by the user that the initial task outcomes are still applicable.

A description of each of the tasks in Step 1 is given in 6.2.2 to 6.2.4. These subclauses also provide practical guidance for the user on how they can be implemented in terms of the discussions to be held, the questions to be asked and the outputs to be produced. Although each task is described separately, the discussions that will take place will cover many of the tasks simultaneously.

6.2.2 Define scope and measures

6.2.2.1 Identify objectives

The objectives shall be agreed upon and documented in accordance with the organization's governance and project procedures prior to the commencement of the life cycle costing activity (e.g. a study). The subject matter (e.g. functions, systems and/or equipment) and the project execution strategies being examined shall be maintained as documented information (e.g. in the LCCMP), to ensure organizational learnings on future situations requiring similar subject matter decision support. In application of the life cycle costing in subsequent phases, this task may be limited to reconfirmation.

Identification of overall life cycle costing objectives should:

a) establish the focus area and the reasons for doing the work;

b) define what functions, systems or equipment are to be examined.

The overall objectives should be discussed with all identified persons who have responsibility for life cycle costing, to ensure they have a full understanding of what needs to be achieved. Potential participants can include the following disciplines:

— design and engineering;

— procurement and contracts;

— health, safety and environment;

— reliability engineering;

— cost estimation;

— planning;

— construction;

— installation and commissioning;

— operations and maintenance;

— economics and budgeting;

— finance and cost accounting.

Discipline participants may come from vendor, contractor or operator organizations depending on project requirements and the life cycle costing subject matter(s). Early scoping studies may not require the involvement of vendors/contractors. Life cycle costing evaluation can benefit from their involvement from the life cycle phase 'Select'.

6.2.2.2 Identify constraints

The constraints which apply to the life cycle costing subject matters in general, and to the competing options being considered, should be identified. These arise from the following three principal sources:

— project constraints on what can be achieved within the life cycle costing work (typically arising from resource and time-scale limitations on the work);

— technical and possibly operational constraints which limit the options available;

— budgetary constraints, such as limitations on CAPEX or OPEX, or alternatively the outcome can be subject to specified economic evaluation measures (e.g. minimum IRR of 10 % before an option merit further consideration).

Constraints can be imposed by third parties or other external influences. Examples of such constraints are regulatory requirements, frame agreements, production quotas, environment discharge, use of BAT or health and safety issues.

All constraints that will impact on the life cycle costing should be retained as documented information.

6.2.2.3 Establish economic evaluation measures

Life cycle costing measures will be quantitative economic evaluation measures, but non-economic issues such as HSE and sustainability (arising from regulation or organization's governance) can also be part of the decision criteria to select amongst competing options.

A range of economic evaluation measures exist. A selection of economic evaluation measures shall be done for the life cycle costing as defined in the LCCMP (see A.1.2.3):

a) net present value (NPV);

b) life cycle cost (LCC);

c) internal rate of return (IRR);

d) profitability index (PI);

e) payback period;

f) break-even volume;

g) break-even price;

h) capital efficiency index (CEI).

These economic evaluation measures and their calculation formulas shall be used in accordance with C.6.3.

For the ranking of options, economic evaluation measures are not always calculated in full, but limited to the estimation of differences (e.g. NPV or LCC). Irrespective of the selected economic evaluation measure(s), the differences between options should be considered under the following three categories:

— CAPEX;

— OPEX;

— REVENUES or LOSTREV.

In the case of competing options where decommissioning costs make a significant influence, the decommissioning costs should be separated out explicitly.

In applying these economic evaluation measures, the need and ability to compare options on a like-for-like basis should be considered. In these circumstances, alternative techniques, such as the use of equivalent annual costs, may be applied.

The economic evaluation measures are not only used to rank the options, but also to provide the basis for determining the cost drivers within an option with implications for the modelling required.

6.2.3 Identify potential options

The identification of potential competing options shall follow a structured approach.

Options and sub-options for the life cycle costing subject matter under review should be identified by a multidisciplinary team.

Many techniques are available to identify options. A well-proven technique to generate options and identify cost drivers is a functional/cost analysis of the investment. This technique is part of value engineering and function analysis workshops (see Clause C.5).

In some circumstances, the options may be predefined as the only potential technical (or operational) solutions available.

6.2.4 Define options

The identified potential options (see 6.2.3) are subjected to a screening process. The method adopted for this process should also be qualitative, as the aim is to find justifiable reasons for excluding options. The output will be an agreed set of options that are subject to both technical/operational and life cycle costing evaluation.

The screening process should be applied consistently, with each option subject to the same assessment criteria. A typical range of screening criteria may include:

— Is it technically feasible?

— Is it practical (constructability, operability and maintainability)?

— Does it meet contract deliverability requirements?

— Can it meet or shorten the schedule?

— Are the risks acceptable (technical, financial, revenue, health, safety and environmental)?

— Is consistent with the objectives stated in Step 1 scoping activities?

— Will it meet current and expected future regulatory requirements (HSE, etc.)?

6.3 Step 2 — Cost drivers and data collection

6.3.1 Objective

The objective of Step 2 is the development of a structured breakdown of cost through consideration of the associated cost elements. The systematic approach defines the cost data to be collected and used as part of life cycle costing activities. Expensive data collection programmes are unlikely to yield significantly greater value than one that contains only the essential information necessary to meet life cycle costing objectives. The critical requirement is to focus on the cost drivers.

The aim is to align the need for information, as defined by the cost elements, balanced with the ability of the project or operation to respond adequately.

Performing Step 2 properly enables greater understanding and appreciation of:

— how to calculate costs;

— how to perform sensitivity analysis with a clear focus on the cost drivers;

— practical issues associated with data collection, such as data sources, access to data, and data quality.

When determining the cost elements in life cycle costing, ISO 19008:2016 shall be considered when classifying these agreed costs.

Annex D contains further information related to data input for life cycle costing activities.

6.3.2 Identify potential cost drivers

A philosophy of including all attributable costs should be adopted. In practice, this is usually tailored to enable the work to be shaped into manageable proportions by limiting it to the significant attributable costs only.

Although the life cycle costing evaluations can be intuitive to a large extent, these evaluations should adhere to the following steps:

a) For each option, identify the costs which incur over the equipment, system or product life. These will be expected to include costs, such as purchasing, operation, maintenance, support services and disposal costs of the option.

b) Address each option in turn, consider the unique features and determine the costs (CAPEX and/or OPEX) associated with each of the following items:

   1) environmental and societal factors, such as footprint, communities where facilities are built and operated, synergy with local industries (suppliers/consumers), other processes, safety systems and transportation;

   2) utilities, such as demands on cooling systems, power generation and accommodation;

   3) supporting infrastructure, such as warehousing, administration services, and other relevant facility support items;

   4) revenue losses, including a clear description of where the losses are incurred, for example at asset, system or equipment level.

c) Compare options to identify the common costs. Where costs are common to all options, a judgment can be made to either include or exclude such common cost elements from the life cycle costing assessment.

The following factors can be considered:

— exclusion of common cost elements where they represent a significant proportion of the total costs can distort the perspective of the assessment;

— inclusion of too many common cost elements can mask key variations and important differentiators between options.

Common costs are normally only included in cases where there are requirements to estimate the absolute costs of owning the asset.

The output from these activities is a list of cost elements for possible inclusion in the life cycle costing assessment. For each option, each cost element shall be reviewed to determine if it is likely to be a cost driver.

The output from this task is a preliminary list of cost elements with the potential cost drivers highlighted.

6.3.3 Define cost elements

The list of potential cost drivers (see 6.3.2) is the basis for the task of defining the cost elements for inclusion in the life cycle costing assessment.

Identification of the cost elements associated with an asset or a system requires both the function of the asset and the interrelationships/dependencies with other systems to be evaluated.

The minimum level of detail necessary to discriminate between the options shall be determined. All cost elements initially identified (see 6.3.2) should be addressed and estimated. The main focus of this task should be to establish the cost elements for the selected potential cost drivers.

For the remaining cost elements, it should be determined if:

— they have any other significance in discriminating between the options;

— it is possible to group any of the cost elements under a single heading, posing a significance in discriminating between the options.

The output from this task is a defined list of cost elements and cost drivers to be included in the analysis.

6.3.4 Identify and collect data

The defined list of cost elements (see 6.3.3) should be structured by considering the way in which costs are acquired and recorded. The way the individual cost elements will be calculated should be considered when creating the cost breakdown structure.

The cost element list should be as accurate as possible to meet the project specific life cycle costing requirements. The output will be a cost breakdown structure.

A review of available data sources should be performed as an initial activity, to ensure sufficient data quality. When the sources of data necessary to obtain the cost elements are established, a data collection process can be implemented with the required quality control.

Annex D contains further information related to the data collection process.

6.4 Step 3 — Modelling and analysis

6.4.1 Objective

The objective of Step 3 is to establish a life cycle costing model in order to:

— produce economic evaluation measures (see C.6.3) showing the difference in cost between selected options;

— produce a ranking of options;

— compare and analyse the cost drivers;

— undertake sensitivity analysis to determine what can change the ranking;

— identify uncertainties and risks.

The quality of both the model and the analysis will be significantly enhanced when a team is involved in the work. A team approach provides different perspectives on the same problem and through such interaction generates additional ideas on the opportunities.

6.4.2 Develop model

An LCC model may be different from an economic model used by operators for other purposes, as its requirement is to compare and rank competing options.

In the majority of cases, a spreadsheet model may represent the most cost efficient and flexible solution, although bespoke software applications can be an alternative. The model developed should be simple enough to be transparent to the users but detailed enough to evaluate the differences between the competing options (see Clause C.6).

Where proprietary or specialized software is used to create models, the outputs should be integrated into the overall model to allow a true comparison between options. This is needed to ensure consistency with the decision criteria defined for the LCCMP.

The LCC model shall be validated to ensure it is credible, accurate and gives realistic results before it is used for analysis.

6.4.3 Analyse and assess

The following information will enable the evaluation to be carried out:

— a ranking of the options in accordance with the decision criteria specified;

— a summary of economic evaluation measures (e.g. life cycle cost, and for each option, identifying the cost drivers).

The results should be evaluated by scrutinizing the ranking and the cost drivers.

To enable confidence in the results, important questions to be answered include but are not limited to:

— are the individual cost totals in line with expectations?

— why do some options perform better than others – can this be explained?

— how does the impact of the timing of the costs vary between options?

6.4.4 Consider uncertainties and sensitivities

The starting point for option elimination should be an examination of the lower-ranked options. From the experience gained in the work, it should be possible to make a judgement on whether these options could ever achieve top ranking. Where there is any doubt, the lower-ranked options may be subject to the same uncertainty and sensitivity checks as the other options.

While estimates by their nature will be subject to some error, what is important is the relative error of one estimate to another and not its absolute error. Where estimates are produced from a common source, the relative error is likely to be reduced since all estimates will embody the same basic assumptions.

For the options that remain, the robustness of the ranking is established by examining the uncertainty associated with the cost drivers in each option. Uncertainties refer to the unknown, single, true value of some quantities needed to predict the estimation used in the life cycle costing. The sensitivity of the options to changes in a number of typical key parameters should be examined (e.g. cost of installation and operation, production profiles, product selling price and exchange rates). Uncertainties also include future events that can happen.

Some options can be better than others in accommodating changes in the production stream or key parameters, such as earlier-than-expected water breakthrough in field reservoir. Where a number of cost drivers for the asset are outside the control of the project, then it is appropriate to perform an uncertainty or a sensitivity analysis in which more than one parameter is changed so as to determine the accumulated effect and the range of uncertainty in the results.

For each factor subject to uncertainty and sensitivity analysis, it shall be established:

a) by how much the estimate has to change to alter the ranking and hence the decision?

b) how likely is the estimate to change by that amount?

These questions should not be addressed in isolation. The views of relevant team members should be included. An output from this task can be the identification of further options.

The considerations for handling data input are included in Clause D.5. Considerations for uncertainties and sensitivities analysis are included in Clause C.7.

6.5 Step 4 — Reporting and decision-making

6.5.1 Objective

The objectives of Step 4 are threefold. Firstly, to report the findings from the analysis and make recommendations in relation to the original decision criteria. Secondly, to commit to a decision informed, fully or in part, by the recommendations and establish how to implement the decision. Finally, to review the application of the 4-step methodology to identify organizational learning opportunities.

6.5.2 Report and recommend

The following should be considered in presenting the results:

a) the ranking allows the lower-ranked options to be eliminated;

b) sensitivity analysis provides the arguments for the preferred solution;

c) sensitivity analysis can also identify opportunities to improve the selected solution;

d) cost drivers identify the potential magnitude of the improvement, either through the definition of new options or changes to existing options.

The recommendations can take three forms:

— the selection of the preferred option, with supporting arguments;

— further iterations, define additional work necessary to further differentiate the options;

— future studies, what work is required in subsequent life cycle phases.

The model, results and recommendations should be included in the final project documentation. The key assumptions for the life cycle costing decision support shall be documented.

Not all life cycle costing assessments will identify a clear choice. For example, the difference between some options can be small and within the range of uncertainty of the options. The selection of the preferred option does not necessarily need to be the highest ranked case, but one that has less uncertainty in the range of results. In these circumstances, the recommendation can be to take the final decision on some other basis.

6.5.3 Decide and implement

The analysis reports and the recommendations will form the basis for decision-making and subsequent project implementation by the stakeholders (see Annex A).

To ensure quality in the selection of the option and the implementation of the selected option, activities to be taken into account include but are not limited to:

— technical and operational basis (see e.g. C.2.2, C.3.2 and C.4.2);

— uncertainty in calculations (see e.g. Clause C.7, Annex D and Annex E);

— constraints;

— management of change (see ISO 20815:2018, Clause C.5);

— project management (see ISO 20815:2018, Clause C.2).

Decision-making is seldomly driven by life cycle costing only. Other business objectives (e.g. HSE requirements) can influence the decision, even if some of these objectives cannot be quantified by economic evaluation measures (see 4.3).

6.5.4 Capture lessons learned

The purpose of the lessons learned or "organizational learning" in a life cycle costing perspective is to communicate positive and negative experiences related to the applicability of life cycle costing in its entirety.

The objective is to continuously improve the application of life cycle costing.

The task is considered relevant for all life cycle phases. When all life cycle costing activities have been completed, this should be summarized per life cycle phase and managed over time.

An organizational learnings register can be developed to document experiences, preferably as a live register through the life cycle phases.

Additional guidance is provided in ISO 20815:2018, Clause C.6.

Annex A
(informative)

Life cycle costing implementation

A.1 Common guidance for life cycle costing planning and implementation

A.1.1 General

This annex provides guidance to common elements of life cycle costing planning and implementation. Common elements are needed for all stakeholders (e.g. operator, contractor and vendor) to introduce and manage life cycle costing activities within each organization.

One main element of life cycle costing is the planning (see 5.4). The planning elements can be included in several coordinated plans or in an LCCMP. The content of a typical LCCMP is provided in A.1.2.

A number of general implementation elements are critical to the successful completion of life cycle cost activities at all life cycle phases, including but not limited to:

— management and coordination of life cycle costing activities; training on the methodology to be used and raising general awareness;

— preparation of a common and consistent source of information and assumptions that can be used as a basis for all life cycle costing studies;

— establishment of data and uncertainty considerations in analyses;

— agreement on economic evaluation measures and the decision-making process: while assessment criteria are decided by the operator, all parties need to understand and apply the principles.

This annex provides guidance on implementation issues for operators (Clause A.2), contractors (Clause A.3) and vendors (Clause A.4).

A.1.2 Life cycle costing management plan (LCCMP)

A.1.2.1 General

This document describes the concept of life cycle costing and the life cycle costing process (see Figure 5) and the activities that require a plan for each life cycle costing subject matter. As with planning of production assurance and reliability management (see ISO 20815:2018, Annex A), a planning document for life cycle costing entitled LCCMP can be beneficial.

The LCCMP is generally used for the entire asset or project by the operator, but can also apply for the engineering contractor or a supplier/vendor, for their scope of work in a project.

The LCCMP should be established in the earliest phase of a project and be updated for each life cycle phase (e.g. in project development and also in operating phase of the asset), to accumulate asset-specific know-how for cost-effective future decision support and enable organizational learning to be available to other similar projects.

The LCCMP should cover the topics listed in A.1.2.2 to A.1.2.7.

A.1.2.2 Terms of reference

A general description of the LCCMP similar to the following may be given:

— purpose and scope in line with the life cycle costing strategy (see 5.4);

— system boundaries and life cycle status;

— revision control showing major changes since last update;

— distribution list.

A.1.2.3 Life cycle costing philosophy and business objectives

A description of the life cycle costing philosophy to enforce business objectives similar to the following may be given:

— description of overall business framework and overall optimization criteria, and referencing to key company or contract documents;

— definition of economic evaluation measures to be used in the LCC analyses;

— definition of the methodology to be used, with reference to the 4-step life cycle costing methodology shown in Figure 4 and detailed in Figure 5, and indication of which of the economic evaluation methods (see C.6.2) is to be adopted;

— definition of the audit requirements, including the number of assessment stages and when assessments will take place, and in particular any requirements for independent assessment of work carried out within each life cycle phase.

A.1.2.4 Project risk categorization

A description of the project risk categorization should be included in the LCCMP to justify the selection of life cycle costing activities, i.e. the life cycle costing subject matters. The project risk categorization in ISO 20815:2018, Table 1 can be useful in this prioritization.

A.1.2.5 Organization and responsibilities

A description of the organization(s) involved with corresponding authorities and responsibilities should be clearly stated in the LCCMP. Descriptions similar to the following may be given:

— the organization(s) and responsibilities, focusing on life cycle costing subject matter(s) business performance, internal and external communication, responsibilities given to managers and key personnel, functions, disciplines, sub-projects, contractors and suppliers;

— the action management system, defining how the recommendations and actions arising from the life cycle costing activities are communicated, evaluated and implemented;

— the verification and validation functions specifying planned third-party verification activities (if any);

— the reporting relationships of those involved in undertaking the work: particularly the reporting relationship with the manager accountable for delivering asset value;

— definition of resource requirements: potentially a team comprising operator, contractor, vendor and consultant personnel;

— training needs: both general (to raise awareness for all team members) and specific (for those who will undertake the work).

A.1.2.6 Activity description and schedule

An outline description of the activities with activity schedules similar to the following may be given:

— overview of the life cycle costing activities during the relevant life cycle phases;

— the plans or references to other documents containing the plans for the life cycle costing activities showing the main project milestones, critical dates and interfacing activities;

— data collection activities and sources;

— clear statements of the relationship between the various life cycle costing activities (e.g. input/output relationship and timing);

— any specific requirements for software tools to be used for modelling;

— description of the life cycle costing deliverables: covering the contribution towards decision-making, establishing an audit trail for future phases and the inclusion of life cycle costing within any future assessments (requirements specification and tender assessment).

A.1.2.7 References

References are made to, and revised as appropriate when updating the LCCMP:

— key project documentation;

— relevant corporate or company requirements;

— relevant international, industry or national standards;

— list of life cycle costing deliverables (documentation).

A.1.3 Life cycle costing function

A.1.3.1 General

The main roles and responsibilities of the life cycle costing function are described in 5.3.

A.1.3.2 Life cycle costing function in the project

A.1.3.2.1 General

In principle, the life cycle costing function interacts with all business functions, and tends to fulfil a central role within the project. The life cycle costing function acts as a conduit between the engineering/design and commercial functions, translating the technical solution into its impact on the commercial and business strategy.

The main roles and responsibilities of the life cycle costing function can be summarized as follows:

— develop and plan the project life cycle costing strategy;

— develop dedicated internal life cycle costing procedures and/or life cycle costing requirements in organization/project procedures;

— facilitate and coordinate study activities;

— be responsible for handover and maintaining project continuity across life cycle phases.

A.1.3.2.2 Developing and planning the project life cycle costing strategy

Strategic issues that the life cycle costing function is responsible for can include:

— early scoping of design option life cycle costing studies in support of concept studies and FEED;

— initiating and maintaining data storage for common data and assumptions;

— specifying the extent to which life cycle costing is to be incorporated in any pre-qualification activities;

— developing requests for life cycle costing information in tender documentation;

— assessment of tender responses in the context of the business case and providing input to design selection;

— establishing initial operations and support budgets;

— identifying critical components of risk-reward strategies in advance of contract award.

It is the responsibility of the life cycle costing function to ensure that:

a) a consistent approach is applied throughout the project;

b) all important decision points with life cycle costing implications are identified early;

c) the scope of the assessment process is adequately identified;

d) resource requirements and timescales are identified.

A.1.3.2.3 Developing internal life cycle costing procedures

The requirement for life cycle costing procedures should be considered at the following two levels:

1) The need for procedures describing how and when to undertake life cycle costing, at what level of detail, etc.;

2) The need for change in existing organization/project procedures to ensure that these supports the implementation of life cycle costing (e.g. the design to procurement relationship) or purchase on the basis of minimum CAPEX. The challenge is to change the process to implement life cycle costing as the “built in” way of working.

A.1.3.2.4 Facilitating and co-ordinating study activities

At the start of the life cycle costing process, the life cycle costing function is responsible for:

— establishing the life cycle costing assessment objectives;

— resource requirements;

— identifying study options;

— agreeing economic evaluation measures and ensuring consistency between targets;

— establishing the communications links with the functions that will contribute to or influence the study;

— identifying conflict between life cycle costing and other functional requirements, such as performance objectives and requirements (e.g. system availability and equipment reliability targets as further described in ISO 20815:2018, Annex F) are specified, and that they are consistent with targets for economic evaluation measures.

An example of life cycle costing coordination is shown in Reference [24].

A.1.3.2.5 Responsible for handover and maintaining project continuity

It is likely that over the life of a development or project, personnel changes will occur and the focus of the work will shift between operator, contractor and vendor across the life cycle phases. It is the responsibility of the life cycle costing function to establish procedures to ensure that continuity is maintained. The principal mechanism recommended to achieve continuity and support the audit trail is to maintain data storage of common data and assumptions.

A.1.3.3 Life cycle costing function skill set and background

The most important characteristics for the life cycle costing function are:

— a business focus that is able to bridge the gap between the technical and commercial functions;

— a broad understanding of all the functions within the organization (given the wide range of interaction required);

— good communication skills: interface management is a significant component of the work; and, a relatively senior individual.

Life cycle costing is within the capability of the majority of existing functions, each offering its own advantages, for example:

— operations and maintenance specialists have a vested interest in ensuring that OPEX is given a voice in the procurement phases;

— estimators have the necessary costing background, usually coupled with a broad understanding of the engineering implications;

— risk and safety specialists are pan-organization or pan-project experts accustomed to interfacing with a broad range of functions;

— engineering/design specialists have an awareness of the impact of options on the overall requirements.

A.1.3.4 Training and competence

The life cycle costing training needs on a project will vary with the size and complexity of the project and with the contract terms and conditions. For example, a complex high pressure/high temperature gas processing plant at the forefront of technology will have many more areas requiring life cycle costing analysis than a simple oil processing platform. Also, life cycle costing should be used extensively on alliance style projects whereas they will not be so relevant on lump-sum EPIC contracts.

Assuming a fairly complex alliance-style project, nearly all project staff will require familiarization with life cycle costing objectives and principles. This can be achieved by mentions in project handbooks, procedures, etc., or via kick-off meetings or team-building sessions to which most staff are invited. Another forum for dissemination of life cycle costing information is during value engineering/cost reduction sessions. It is vital that commitment to life cycle costing is shown by top management for the technique to be effective.

More specific training in life cycle costing methodology (see Clause 6) and associated techniques (see Annex C) and models should be provided for the engineering manager and their lead engineers, together with any project engineers. This could comprise a course which explains the principles and practice of life cycle costing. Further training should be cascaded down from the lead engineers to others who may be required to use life cycle costing techniques. This training may take place "on the job". Training in life cycle costing should be managed and audited by the life cycle costing function to ensure consistency of approach and conformance with the project life cycle costing guidelines.

A.1.4 Contractual issues

A.1.4.1 General

As mentioned in 5.5, the relationship between life cycle costing and contractual strategies is an important matter. It is important that the contract is encouraging a collaborative spirit.

A.1.4.2 Prequalification

From a customer standpoint, the intention of prequalification is to reduce the number of eventual tenderers to a manageable level. Extending prequalification criteria to incorporate references to life cycle costing may include the following requests:

— the potential tenderer's internal procedures for estimating and generating life cycle costing estimates and how they relate to this document on life cycle costing, the intention being to elicit information on the extent to which life cycle costing is integrated into their engineering and business processes;

— relevant previous experience in the application of life cycle costing, paying particular attention to the benefits that were achieved;

— the understanding of the financial framework and economic methods applicable to the work;

— their access to data/information (with sufficient quality) to support their ability to conduct life cycle costing assessments;

— an indication of their willingness to agree to contracting to elements of life cycle costing;

— demonstration of the understanding of cost elements and applicability of related disciplines such as cost estimation coding (per ISO 19008:2016);

— demonstration of the understanding of production assurance and reliability management (per ISO 20815:2018 and ISO 14224:2016) that will be needed in the life cycle costing activities (see further information in Annex C).

To incorporate the contribution that contractors and vendors can make in early life cycle phases, it may be possible to develop contractual framework arrangements that allow discrete studies support the operator strategy and policy for life cycle costing (see 5.4). The advantages of this approach are that it:

— provides an economic route to enlisting expert advice;

— does not preclude the ability to compete subsequent life cycle phases;

— introduces continuity across the life cycle phases by allowing the development of partnering arrangements.

This approach will significantly improve the business benefits and contribution of life cycle costing activities as defined in the LCCMP (see 5.1) or planning documents, and simultaneously improve communication and awareness between participants.

A.1.4.3 Tender documentation

The tender document should reflect the need to maintain life cycle costing continuity through each life cycle phase by defining the need for responses to questions that relate to the use of this document, such as:

— the tenderer's approach to conducting life cycle costing;

— the range of options that will be considered and how a solution will be identified;

— estimating and modelling techniques to be applied (adherence to life cycle costing techniques, see Annex C);

- analysis to be applied to the outcomes (sensitivity analysis and trade-off analysis, identification of cost drivers);
- statements on the information required from the operator (economic evaluation measures, level of design definition, cost breakdown structure and relations to ISO 19008:2016);
- proposals for overcoming deficiencies in access to data, data quality and reducing uncertainty.

To reduce potential clarification questions from tenderers, the operator can provide the following information:

- specific options to be considered (e.g. the requirements for a baseline option);
- data to be provided, such as cost rates (e.g. manpower and transportation), expected revenue, production rates, taxation and required rates of return;
- reporting requirements, such as frequency, level of detail, information handover requirements to the next life cycle phase;
- the marking scheme: the relative importance of life cycle costing activities for value creation within the overall response.

Some of this information can be sensitive to the operator and may be substituted by "industry norms" or synthetic rates. Real data may be released once a contract has been let.

The tender documentation should enable the bidders to respond to life cycle costing requirements in a common and consistent manner. In addition to the topics identified above, features that can assist with this process are:

- specification of the cost elements: the cost breakdown structure (i.e. ISO 19008:2016 unless otherwise specified) to be used by the tenderer (where preparatory work has exposed the cost drivers);
- statements of contractual intent: specification of the cost elements to be included in future contractual negotiations (e.g. all CAPEX and selected OPEX cost elements);
- issue of a "standard" LCC model: model to be used by all tenderers in their response; while offering advantages in standardizing the response, this approach places the burden on the operator to produce a competent and comprehensive model;
- release of a project comparator: this could be the results of previous work that has led to a particular option being favoured, for which the objective is to provide a target for the tenderer to meet and improve upon;
- supporting justifications: a requirement for the tenderer to justify the data used in the response, in which the principal focus of this is to ensure that bidders do not provide overly optimistic estimates.

To realize the full benefits of life cycle costing, the tender document uses functional specifications since the use of prescriptive technical specifications constrains the tenderer's ability to innovate and reduces the potential business value of life cycle costing.

A.1.4.4 Contract award

Current industry practice includes the use of gain share contracts with a risk/reward strategy focused towards the CAPEX elements. By including life cycle costing within the process, decisions taken on a CAPEX basis can be better informed on the value of the investment in relation to the potential resulting consequences. Within this contractual regime, the operational and support (OPEX related) aspects can be taken into account through measures such as:

- insisting that all proposals for CAPEX improvement be accompanied by an assessment of LCC implications, specifically to examine the risks to the maintenance of an acceptable NPV;

— using the LCC estimates as the basis for developing the OPEX budgets;

— insisting that no CAPEX reductions are considered that reduce the project NPV.

Normally, the majority of contractors and vendors have no control over how the facility or systems are used once commissioned. An approach to extending the contract arrangements into the operations and support phase (e.g. service contracts) may include:

— consideration of low-risk items or support cost elements as candidates for firm price support arrangements from the contractor and/or vendor;

— extension of contracting terms to incorporate service provision against specified performance targets, such as required technical availability or reliability (see ISO 20815:2018, Annex F);

— risk/reward schemes based upon the support contract value balanced by the contribution of the individual system/equipment to NPV.

The consequence of these changes is that data will assume a contractual status, driving the establishment of accurate data collection and analysis techniques by the contractors and vendors to support the work. This experience will lead to better estimates for future life cycle costing activities, but the difficulties of comparing actual performance with data assumptions should not be underestimated. If performance targets are established for the operating phase, this will also require follow-up to ensure verification of requirements fulfilment (see ISO 20815:2018, Clause F.3). Further information is also given in ISO 14224:2016 and ISO 20815:2018 with respect to organizational learning, reliability and maintenance data collection and analysis, etc.

A.1.4.5 Alliances

All the general features described in A.1.4.2 to A.1.4.4 are equally appropriate to alliances and partnering contractual schemes. In addition, the following specific issues should be resolved within the work share agreement:

a) a statement on how potential conflicts that arise during design optimization will be resolved (e.g. CAPEX/OPEX trade-offs can change the financial value of individual participants' contributions to the investment);

b) definition of the resourcing and responsibility for life cycle costing activities;

c) the use of this document as the single standardized approach to life cycle costing across all participants, such as common procedures and common models;

d) equality of life cycle costing information;

e) agreed economic evaluation measures (see C.6.3).

Concerning organization of life cycle costing activities, and when technical and commercial responsibility are being transferred to contractors, it is likely that they will undertake the LCCMP activities with support from vendors.

Concerning economic evaluation measures, this is of particular relevance where contractors and vendors are assuming significant risk. In this instance, the decision criteria are influenced by their needs in terms of return on investment.

A.1.5 Communication

A.1.5.1 The communication between participants

The objectives of a life cycle costing-based procurement are:

— for the operator/contractor, to evaluate the solutions offered by the vendor based on added value to the project;

— for the vendor, to evaluate and select the solution, based on the vendor's range of products, that offers the most value to the customer.

The operator and contractor's attention will generally be focused towards the bid evaluation. From the vendor's perspective, the greatest potential lies in offering the optimum solutions to fit the need from the variety of solutions the vendor can offer. The most important factor in achieving the objectives of all participants is two-way communication as illustrated in Figure A.1.

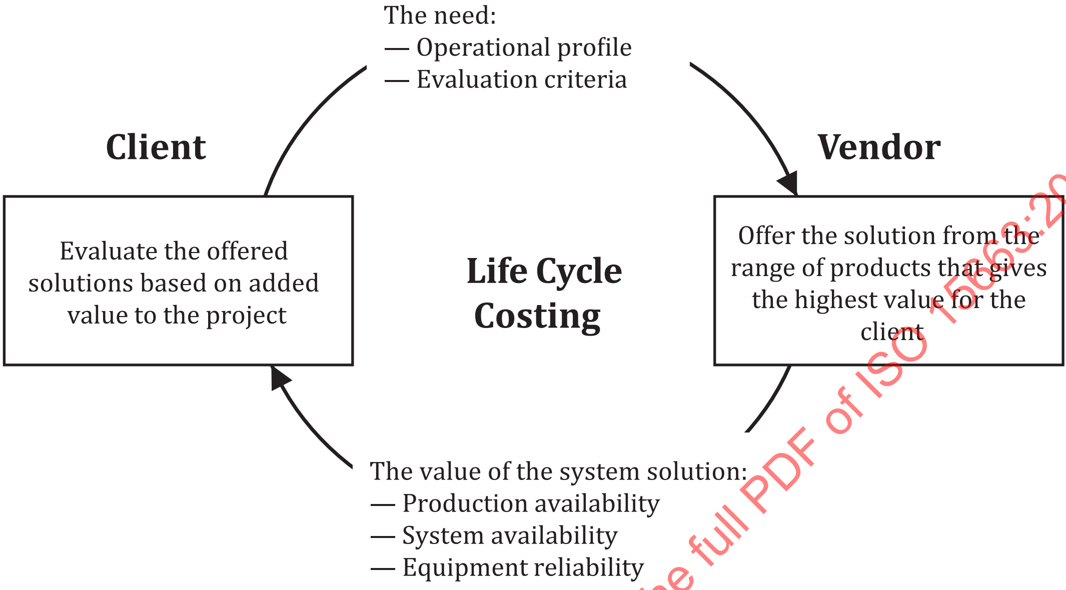


Figure A.1 — Two-way communication between vendor and client

To enable the vendor to offer the best solution to cover the needs, the client should communicate, or the vendor should request, the following:

a) the need (e.g. capacities and operating level over the lifetime);

b) targets for economic evaluation measures, and how to balance OPEX against CAPEX;

c) constraints, such as limitations on topside weight, power consumption, footprint or access for maintenance;

d) cost parameters outside the vendor's control (e.g. energy costs) in order that the vendor can perform the trade-offs between alternatives, such as high efficiency and high price vs. low efficiency and low price.

For the vendor, communication is focused on:

— ensuring they have adequate information to optimize their offer against the client needs;

— demonstrating the value of the solution to the client (e.g. in terms of lower cost, maintainability, efficiency or reliability).

The client will only evaluate the solutions offered. However, vendors are often unable to offer the solution from their range of products that best fits the client's need. This is normally due to lack of information on the client's need, perception of total value and evaluation criteria.

Further guidance on communication regarding data for life cycle costing is given in Annex D.

A.1.5.2 Responding to life cycle costing enquiries

When responding to an enquiry based on life cycle costing, the main issues are to:

— clarify the evaluation criteria and their impact;

— identify the client's need, operating level and conditions over lifetime;

— clarify the access to data from the customer, together with the data requirements for the bid;

— identify the cost drivers;

— put together a package that gives the lowest LCC, and/or meet other defined economic evaluation measures, by focusing attention on the cost drivers;

— demonstrate the value of the package solution in the bid response.

The focus should be on how the bids will be evaluated and on the client's need. When the cost drivers have been identified, the potential for cost reductions (arising from design improvements or changes in the support or maintenance strategy) can be defined. Alternatives which indicate reduced LCC can be evaluated in relation to their impact on the offered price.

The focus should be on the areas where added value to the client can be demonstrated, and on how to communicate the value or the cost reduction potential for the package.

A.1.5.3 Life cycle costing evaluation of vendors or subcontractors

A bid evaluation, in which life cycle costing is covered, requires:

— an integrated technical and commercial evaluation;

— technical differences to be quantified and form part of the commercial evaluation;

— the cost drivers and the elements/parameters affecting these to be identified.

It is on the design differences, in the form of efficiency curves, capacities, configurations and resulting performance measures (e.g. production availability and system availability), that cost differences can be identified and qualified.

A.2 Operator implementation issues

A.2.1 General

This clause addresses the main topics to be considered by an operator for establishing, managing and practicing life cycle costing, including:

— specifying the full life requirements in the contractual frame and including it in the tendering and awarding procedures (e.g. considering technical advice weighted with commercial price, or awarding on the basis of life cycle costing);

— developing a contract strategy in which contractors and vendors can be committed to deliver life cycle costing (e.g. with incentives, guarantees, operation and maintenance services, build, own, operate contracts).

From a life cycle costing implementation perspective, the life cycle phases (see Clause B.1) illustrates several aspects of the operators' role:

— The decisions taken at the life cycle phase 'Select' determine the majority of LCC.

— Given the overlapping role of the participants, a growing number of developments proceed on the basis of alliance partnerships, with impact on the role of the operator in life cycle costing, specifically in developing and describing requirements and communicating these requirements to partners and suppliers.

— The contractors may have involvement in the early life cycle phases (e.g. life cycle phase 'Select' and later also operating support with vendor assistance in the life cycle phase 'Operate'). Life cycle costing can assist established project risk management techniques or production assurance and reliability management (see ISO 20815:2018) by offering a common basis for communication in this process.

— Operators initiate additional life cycle costing studies during the 'Operate' life cycle phase either at set times (e.g. annual review) or resulting from operational insight (e.g. observation of obsolescence, spares not being used, or differences in reservoir performance). The degree of vendor and contractor involvement will depend on the type of study and input requirements needed.

The implementation of life cycle costing for the operator should take the following key issues into account:

— Commitment: This has primarily arisen as a contractor and vendor concern, that operators will specify the use of life cycle costing, but ultimately take the procurement decisions on the basis of lowest competitive CAPEX. Conversely, the operator may specify life cycle costing as a component of the decision criteria in a competition, but finds contractors delivering superficial responses because the contract extends only to CAPEX.

— Risk: Life cycle costing brings its own particular perspective to established risk assessment and risk management techniques. This is an interface issue.

— The contracting strategy: The objective is to establish contracts on the basis of life cycle costing at the interfaces. Contracts based on life cycle costing are difficult to implement due to problems of measurement.

A.2.2 Commitment to life cycle costing

A practical approach to embody life cycle costing within company governing documents can include:

— reference to how this document is reflected in corporate governance;

— assignment of responsibilities for the provision of data input to life cycle costing;

— a common content, format and structure for the evaluation of competing options;

— communication of how life cycle costing is applied in a quality manner.

Framing such operator governance into contractor requirements can be achieved through measures such as:

— inclusion of requirements in invitations to tender;

— prescription of capability and experience as a pre-qualification criterion;

— provision of operator life cycle costing information to the contractor;

— identification of performance requirements;

— provision of how life cycle costing will be weighted in the overall bid evaluation.

A.2.3 Life cycle costing — A business focal point

A.2.3.1 General

The unique aspects of the life cycle costing function within the operator organization (see 5.3) are:

— defining the life cycle costing strategy;

— providing continuity across life cycle phases;

— knowledge and competence of life cycle costing.

A.2.3.2 Defining the life cycle costing strategy

Defining the life cycle costing strategy should include the following commercial considerations:

a) asset ownership: there are significant implications for the role of life cycle costing where lease or rent versus purchase features;

b) competition: how the LCCMP defines the role and extent of life cycle costing in the pre-qualification, requirements specification and tender assessment;

c) procurement source: alliances and partnerships can limit the technical solutions and options for operation and maintenance;

d) operations support: life cycle costing can assist in assessing the potential for contractor/vendor operation;

e) procurement strategy "knock-on" effects: decisions taken during procurement can limit the range of options that life cycle costing can consider for operations (e.g. scope for independent competition);

f) performance: life cycle costing can assist in identifying contractual performance measures for critical elements by identifying the data requirements from a life cycle costing standpoint;

g) flexibility during operations: given potential changes in use through life (e.g. field size, production rates and chemistry), life cycle costing can quantify the effects of uncertainty and the resultant CAPEX/OPEX trade-offs;

h) disposal: life cycle costing can expose opportunities for asset re-use or redeployment and consequential impacts on the current operating phase.

The following matters should also be considered:

a) start-up date: the scope for accelerated procurement, its value and the sensitivity of NPV to changes;

b) project development: the implications of life cycle costing within a larger development project;

c) procurement boundary: there can be life cycle costing implications for items that lie either at the boundary or outside the boundary of the proposed procurement (e.g. downstream facilities);

d) cost breakdown structure: what level of detail to be considered at each life cycle phase to reflect uncertainty in the estimates;

e) budget considerations: what financial constraints exist on CAPEX that limit the range of commercial and technical options and limit trade-offs between CAPEX and OPEX for NPV improvement;

f) focus: decisions may be driven by commercial considerations or technical considerations; life cycle costing should assist in highlighting the dominant issues to be addressed in the next phase;

g) timing: how long can decisions on operations be deferred (e.g. until more accurate life cycle costing information becomes available);

h) timescales: life cycle costing can assess the impact of differing periods of contractual support, taking into account production profiles, life extension, upkeep cycles and planned updates;

i) other support programmes: assessing the impact of external dependencies such as existing spares pools, preferred suppliers, equipment and internal infrastructure;

The life cycle costing strategy should be implemented in the contract documentation (see A.2.5).

A.2.3.3 Providing continuity across life cycle phases

The life cycle costing function has a responsibility for ensuring that all significant life cycle costing assumptions made during different life cycle phases are consistent. The important feature is to ensure continuity throughout the life cycle phases, for example:

— initiated by the operator during the life cycle phase 'Select';

— updated by the contractor during the life cycle phase 'Define';

— maintained by the contractor during the life cycle phase 'Execute' with input from vendors;

— used as the baseline to assess proposed changes during the life cycle phase 'Operate'.

The LCCMP should be updated throughout the life cycle phases to reveal the use of life cycle costing and lessons learnt.

A.2.3.4 Knowledge and competence of life cycle costing

The operator should have competence in life cycle costing methodology and supporting techniques (see Annex C). This should be described in the operator's corporate governance to cover framework, context and desired outcome.

A.2.4 Risk — An operator's perspective

A component of life cycle costing is the identification and quantification of the major risks associated with the recommended option and its engineering and design, support and contract strategy. The outcome of life cycle costing contributes towards the content of the risk register (see ISO 20815:2018, Clause C.2). Life cycle costing can assist risk management by:

— quantifying the subjective outcome of the risk assessment in a common and consistent manner, which would typically concentrate on the high/high risks and measure their impact;

— providing additional focus to the assessment through identification of the cost drivers.

Once included in the risk register, the life cycle costing function can assist in developing mitigation strategies in specific areas, such as:

— minimizing risk to revenue through examination of CAPEX/OPEX trade-offs that improve operating performance;

— quantifying the effect of project schedule slippage or acceleration as an input to a risk/reward scheme;

— valuing risk transfer for specific components as part of a contracting strategy.

A.2.5 The contractual framework — An operator's perspective

A.2.5.1 General

Most contracts placed by the operator for project development are CAPEX based. These are implemented in variety of different ways, ranging from lump sum to gainshare where the contractor assumes some risks. Life cycle costing introduces an OPEX perspective and it may be incorporated into existing contractual frameworks with varying degrees of risk transfer. The following two alternative approaches illustrate the range of contractual impact:

— where life cycle costing is used to influence the design;

— where life cycle costing is used to assist identifying and contracting for elements of operation.

These alternatives represent an increasing commitment to, and reliance upon, life cycle costing as part of the overall contracting strategy. They may be introduced sequentially, where the individual approaches are introduced progressively on a project-by-project basis, each one building on experience gained, where more than one approach is introduced into a single project simultaneously.

A.2.5.2 Influencing the design

To influence the design, a fast and efficient process should be in place within the project to allow additional CAPEX to be justified.

This option has no contractual significance to the contractor other than a requirement to undertake life cycle costing work to support and optimize the identified design. In defining the contractual requirement, the operator should:

a) identify the requirement to the contractor to undertake life cycle costing;

b) identify the assessment criteria by which the contractor is to assess trade-offs.

A.2.5.3 Contracting elements of operation and support

In this context, the operator seeks to achieve progressive risk transfer to the contractor through firm price contracts for elements of operation. In addition to the contractual requirements, the operator should also:

a) state their intention to contract for specific support elements;

b) set financial targets for the elements of support that will be contracted out;

c) propose timescales for the period of support.

The operator may wish to seek independent estimates to identify the targets and that there will be increased focus on the risk assessment undertaken by the contractor.

A.2.5.4 Contract administration

To support incentive schemes within a contractual framework based on life cycle costing, a form of standard costing system should be provided to measure performance and achievement. Activities associated with this should cover the collection of actual cost and performance data for analysis and comparison with agreed targets.

As part of the contract, negotiation arrangements should be made as to how future changes arising from practical operating experience can be accommodated during the currency of the contract and within the incentive arrangement. The contract should include agreed methods covering:

a) future proposals for OPEX improvement and how they can be accompanied by an assessment of life cycle costing implications, specifically to examine the risks to the maintenance or improvement of NPV;

b) structure of the operator and contractor/vendor team to evaluate and agree the proposed changes;

c) data collection and its role in supporting the assessment of performance.

A.3 Contractor implementation issues

A.3.1 General

The main topics to be included for a contractor (e.g. engineering contractor) for establishing, managing and practicing life cycle costing are addressed in this clause. The contractor can also be an EPC contractor, EPCI contractor, EPIC contractor, drilling contractor, etc.

The basis on which a contractor will conduct life cycle costing activities within a project will depend on the operator's requirements. On some contracts, the role of the engineering contractor could be restricted to determination of the best life cycle costing solution for given field data, a final product requirement and specified economic evaluation measures. In other contracts, it can be beneficial to extend the contractor responsibility both to earlier and later stages of the asset life cycle. The range of involvement by contractors in terms of level of detail and life cycle phase is indicated in Figure 2.

The contractor, with their relationship to both operator and vendor, has a pivotal role and in this respect is key to the successful use of life cycle costing within the industry. The key issues in implementing life cycle costing within the contractor are:

— the development and organization of a capability: it is likely that the majority of life cycle costing work is undertaken by the contractor, with the operator coordinating and specifying the requirements at a high level;

— contractual risk: the extension of the contractors' role into early and later life cycle phases will lead to greater involvement in life cycle costing risk identification and assessment, together with the assumption of contractual risks for elements of support.

A.3.2 Developing and organizing a capability

A life cycle costing capability is developed by a contractor in order to meet the requirements of operators. This can be met by existing project team members (given suitable training) or from a centralized function. The advantage of a central function for life cycle costing expertise is that it provides consistency across the organization.

Within the constraints defined in the operators' requirement, life cycle costing includes the following activities:

— identify the need for undertaking life cycle costing in the contract;

— establish with the operator project-specific economic evaluation measures;

— perform an initial assessment to identify those components that contribute significantly to NPV, i.e. cost drivers

— focus more effort on high-risk items (e.g. high impact cost drivers or project schedule critical);

— constrain the data requirements to reflect the level of design definition, focus on design differences and use sensitivity analysis to quantify uncertainties in data and estimates;

— use the best available data from operators, contractors, vendors or other organizations;

— apply life cycle costing within the organization and adapt or map onto the different requirements from operators.

The abovementioned activities will cover a range of topics, such as modelling techniques, input data estimation and cost breakdown structures. This does also require the knowledge and use of ISO 19008:2016, ISO 14224:2016 and ISO 20815:2018. See also Annex C and Annex D.

Vendors of critical equipment and systems are an integral part of the process, whether introduced to the project through competition or as a partner. The criteria used in selecting vendors can be split into two broad categories:

— Those where life cycle costing assessment of their products will add no value and where the vendor has no requirement to develop a life cycle costing capability, i.e. off-the-shelf items such as galley equipment.

— Those supplying systems and equipment where there is opportunity to optimize the design from a life cycle costing standpoint. Consideration should be given by devolving work to those critical equipment vendors who have developed a life cycle costing capability. For others, the contractor will have to provide significant support in the assessment of their equipment and systems.

A.3.3 Risk — A contractor's perspective

For the contractor, life cycle costing can assist in the extension of their role into areas such as maintenance management, integrated service provision and engineering services. These opportunities also present the contractor with potential for additional risks and associated potential for rework, dependent on the contractual scope of work defined by the operator. The points below identify the role of life cycle costing in supporting existing business (design trade-off) and extending the business (contracting for support). Each point represents increased financial risk (and opportunity) to the contractor:

— design trade-off**;** where life cycle costing is used as a design trade-off tool, financial implications to the contractor can arise through technical performance guarantees;

— contracting for elements of support**;** where use of life cycle costing has a direct financial consequence to the contractor through the prices quoted.

Guarantees required by the operator may be accompanied by contractual penalties for failure to meet the technical performance requirement. Life cycle costing can provide a quantitative basis for assessing the impact of performance variation on production revenue by:

— reviewing the specified level of performance: a relaxation may enable the contractor to offer a lower-cost or lower-risk solution leading to an improved NPV for the operator;

— assessing the level of incentives and penalties in relation to the contractor's performance for contractually agreed targets on NPV.

The most effective mechanism the contractor can use to tailor the work is a top-down approach. This approach focuses on the range of options examined and sacrifices the level of detail considered to ensure that the coverage is complete. In early life cycle phases (such as 'Select' and 'Define'), it may be possible to defer work to later life cycle phases without compromising the value of the work undertaken.

A.4 Vendor implementation issues

A.4.1 General

The range of involvement by vendors in terms of detail and life cycle phase is indicated in Figure 2. For the vendor, life cycle costing can be used to demonstrate improved service and quality, thereby extending their role beyond equipment supply. As such, the specification of life cycle costing from clients does not constitute a risk, but represents a potential for increased opportunity and profitability, by adding value to a field development project in all life cycle phases through vendor involvement.

For the vendor to achieve this potential, a value-optimization competence is required. In addition, there are challenges that should be addressed with regard to equipment performance (i.e. reliability data and operational data), internal competence and contracts.

A.4.2 Application of life cycle costing for the vendor

While the requirement to undertake life cycle costing can be specified by customers, its impact on the vendor is somewhat different from that on the customer.

For the operator, life cycle costing is concerned with optimizing CAPEX, OPEX and revenue, with the focus generally on the CAPEX/OPEX trade-offs. As such, for the operator life cycle costing is primarily focused on their costs. For the vendor, life cycle costing impacts on both income (product sales) and costs. This is shown in Figure A.2. The vendor contractual relations are normally related to the engineering contractor or EPC contractor (as customer) or also directly towards the operator.

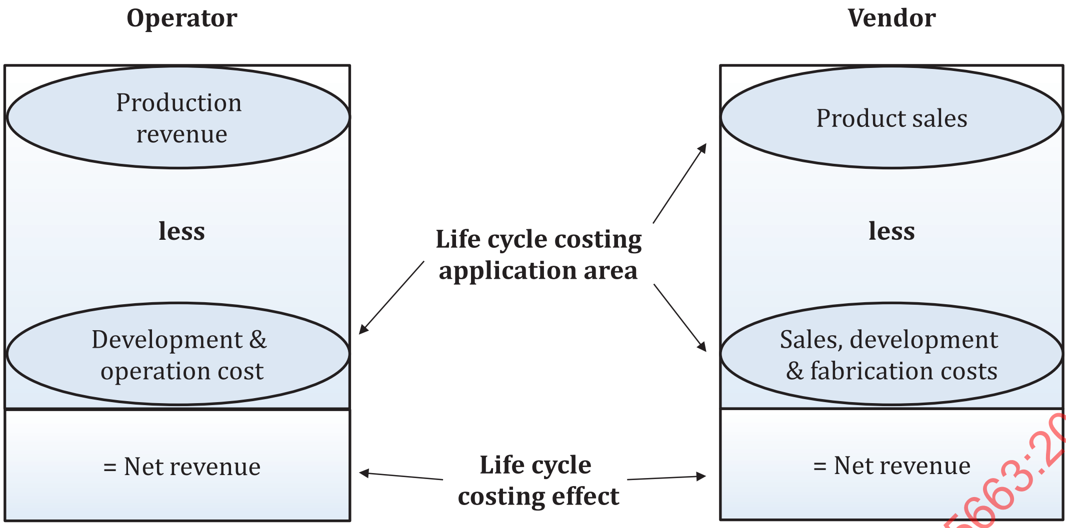


Figure A.2 — Life cycle costing can affect vendors' income and costs

The aim of life cycle costing is to optimize the operator's profitability. The consequence for the vendors is that it can adversely affect both the vendors' sales revenue and costs. To counter this, the vendor should focus their attention on using life cycle costing to improve the products which generate income.

The critical areas in the short term for the vendor are the following:

— the ability to be awarded a purchase order;

— the internal competence of the vendor to deliver and demonstrate added value to customers;

— client dedication and competence;

— the speed of the change.

The critical areas in the long term are to stay competitive through:

— Integration of economics into all functions of the company, leading to lower-cost production: Functions to be considered leading to lower-cost production include production, maintenance, warehousing, logistics, marketing and procurement.

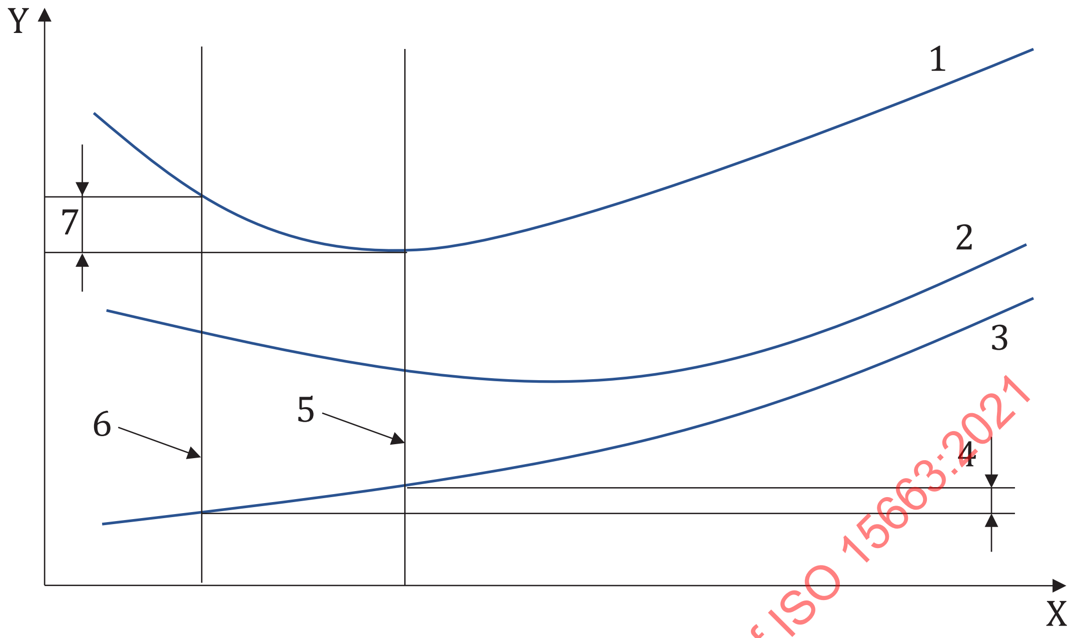
— Development of new life cycle costing-based system solutions: The vendor is no longer simply selling equipment but supplying package solutions to meet overall client's need. The vendor should be able to demonstrate an understanding of the project life cycle and how they can contribute to lowering costs through competences in production, engineering, product development (especially in relation to framework agreements), maintenance and support, and optimization.

In all of these, the vendor should also be able to demonstrate how their equipment/systems will be used.

The vendor's competence in the production and engineering fields will typically be demonstrated by their equipment and unit prices. With vendor involvement in the development projects, the focus will shift more towards the overall competence of the organization. The vendor's product strength will be the competence to arrive at the most cost-effective solution for the total package to fill a function over its lifetime. This will spread throughout the supply chain, and is equally applicable for the relationship between vendors, their suppliers and subcontractors.

A.4.3 Profitability potential for vendors

The opportunity for the vendor in the application of life cycle costing is illustrated in Figure A.3.



Key

X equipment complexity

Y cost

1 LCC

2 OPEX

3 CAPEX

4 vendor opportunity

5 best solution

6 minimum acceptable technical requirements

7 operator opportunity

Figure A.3 — Life cycle costing providing an opportunity for the vendor to demonstrate that higher-cost equipment adds value

The adoption of functional specifications can lead towards solutions offering the minimum acceptable technical performance with competition on lowest price. This may be in neither the operator nor the vendor's best interest. The use of life cycle costing can arrive at the optimum solution (as defined by the operator's decision criteria) that maximizes operator profitability, even if this increases the initial cost. This provides the potential for the vendors to improve their profitability through offering higher-value equipment and demonstrating added value to the client.

If the vendor can build up an understanding of the operator's total costs in relation to the vendor's equipment, this will result in the following:

— the vendor improving their revenue by getting paid for improved quality, efficiency or maintainability by demonstrating added value to the operator;

— the client achieving lower total cost for the function the equipment is to fulfil and thereby improving profitability;

— the vendor being better placed to extend the scope of their supply by contracting for elements of support.

In addition, the vendor's contribution towards design improvements, for example by being involved in the life cycle phase 'Define', can be reimbursed based on commercial competitiveness.

In offering options which have increased CAPEX justified by the expectation of future OPEX savings, the operator should take into account the possibilities that expectations cannot be realized.

A.4.4 Contracts – A vendor's perspective

Definition of how the selected alternative and its equipment performance will be monitored during the life cycle phase 'Operate' is difficult to quantify even after the costs have occurred. Why costs turn out to have a different magnitude than estimated is also hard to demonstrate, thereby presenting challenges in obtaining legally binding guarantees.

Another obstacle is that vendors may not be willing to accept a responsibility for the life cycle cost. Unless they have collected and analysed information on the equipment performance (e.g. reliability data) that constitute part of the OPEX of their equipment, they should be faced with considerable uncertainty in the costs, and this will attract a high-risk premium. This means that the cost can increase.

Another approach is to require guarantees on the elements affecting the cost drivers, like efficiency curves and performance over time.

Combined purchase and maintenance contracts make life cycle costing-based bid evaluation easier, since the vendor is directly responsible for significant elements of the OPEX.

For all parties (e.g. operator, contractor and vendor) the most difficult contractual aspect in relation to life cycle costing is the topic of bonus and incentive schemes.

The operator's profitability is derived from overall performance and costs over life, whilst the engineering contractor's and the vendor's profitability are related to the contract payment from the operator, usually supported by a bonus where a technically acceptable solution is delivered under target CAPEX and on time.

As long as the focus of the operator is to develop the field at the lowest possible CAPEX, the incentive schemes are orienting the parties to work in the same direction. With a focus on life cycle costing, a different approach to bonus and incentive schemes is necessary.

For the vendor, the issue of how to split the cost savings/added value is much easier. As long as life cycle costing is the evaluation criterion, the vendor may decide it as shown in Figure A.4.

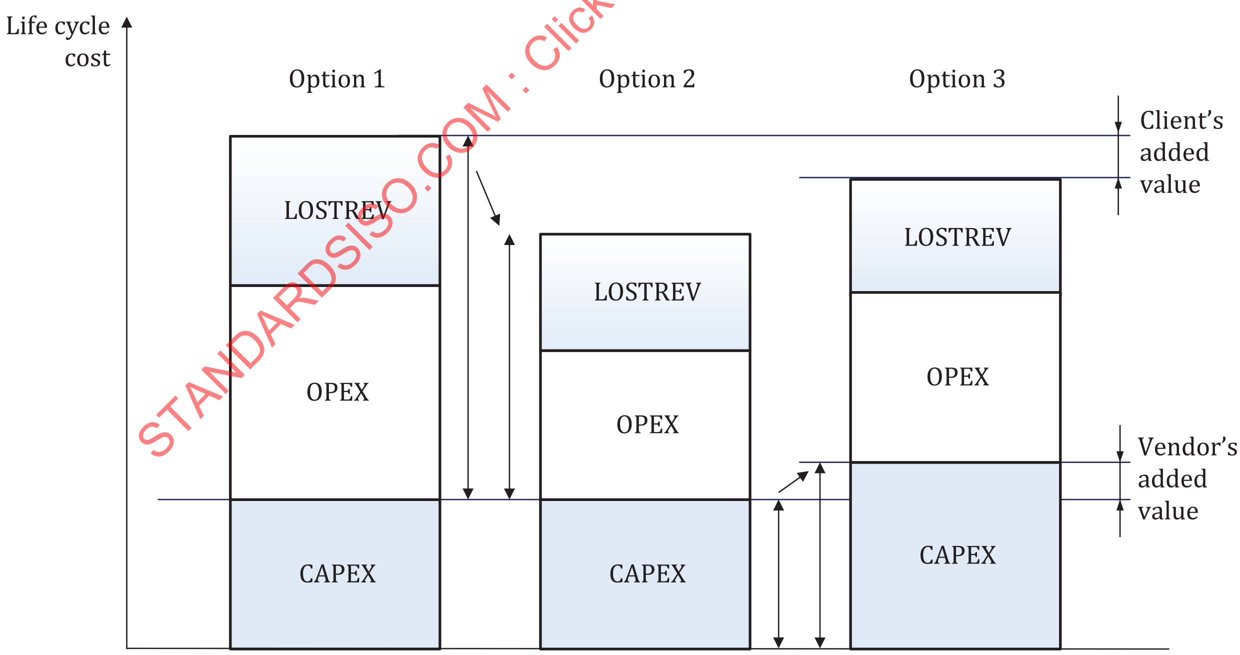


Figure A.4 — Incentive schemes to the benefit of all parties

Solutions with lower OPEX or lost revenues (see column 2 in Figure A.4), have a higher value for the client compared to traditional solutions with the same CAPEX (see column 1 in Figure A.4). To enable a vendor to offer the solution which optimizes the LCC, it is likely that an increased investment will be needed and, in order to remain profitable, this will be passed onto the client in the form of a higher initial price. This will then result in the situation shown in column 3 in Figure A.4. The vendor and the client thereby share the investment and the benefits arising. It is important for the vendor to be able to demonstrate to the client that this additional investment offers an appropriate return. An incentive scheme may be built into the contract as a method of securing this arrangement between the vendor and the client.

Independent of approach, incentive schemes should have bonus and penalty limits. The aim of any guarantee is to ensure that what is promised is delivered. While the operators and contractors are aware of the need to balance bonus and incentive schemes with the vendor's financial commitment, the vendor should suggest mechanisms for how this may be achieved. The aim is to ensure that the vendor receives an equitable share in any NPV improvements delivered to the operator.

When considering what can be justified as an equitable share, vendors should understand that uncertainties associated with contracting on the basis of life cycle costing may result in operations having both higher initial price and higher future OPEX not recoverable from the vendor. Each contract should be considered on an individual basis and an appropriate contract scheme developed.

When carrying out life cycle costing and comparative alternative evaluations, it is important to recognize that costs are assessed from the client's perspective; it is their value that will be optimized. Factors to bear in mind are to adopt the client’s calculating/optimization assumptions, use an appropriate level of detail and focus on design differences, gain access to operational experience, and be clear on the economic evaluation measures.

A.4.5 Vendor competence

A.4.5.1 Challenges

The main challenges facing the vendor when integrating life cycle costing within their organization are:

— integrating economics/life cycle costing into the engineering disciplines, so that life cycle costing becomes part of the engineering process focused on client needs;

— convincing the client that the alternative solutions offered constitute the most profitable outcome for the client;

— establishing a role in early life cycle phases and assisting in the definition of the project need.

The first item requires all disciplines to be involved, including marketing, sales, engineering and development, while the second and third items involve building up a capability in demonstrating the value of the vendor's own solutions and his optimization competence.

Vendors are more likely to assess the requirement in their area of competence more accurately than the operator or contractor. This competence can be used to assist in the assessment of different concepts, leading into the assessment and specification of system solutions in the life cycle phase ‘Define’.

A.4.5.2 Training

For the vendor, the most important issue is developing an understanding of the operator's needs through industry initiatives such as:

— developing an understanding of how to undertake life cycle costing activities;

— common industry training programmes;

— integration into the education system.

Annex B
(informative)

Life cycle phases

B.1 General

The primary purpose of life cycle costing is to assist in the delivery of the highest possible added value, i.e. profit, within a field development or project. It achieves this by extending profit improvement opportunities through a process of progressive optimization. The greatest benefit is realized when life cycle costing is integrated across the entire life cycle. While the life cycle costing principles are identical across all phases, the organization in each phase differs in terms of:

— the actions that need to be taken;

— the contribution each participant can make.

Figure B.1 shows the life cycle phases of a field development project together with some of the relevant processes and decisions for each phase, which may be the subject of life cycle costing activities. The processes in Figure B.1 apply to both the original field development and subsequent changes made to the design.

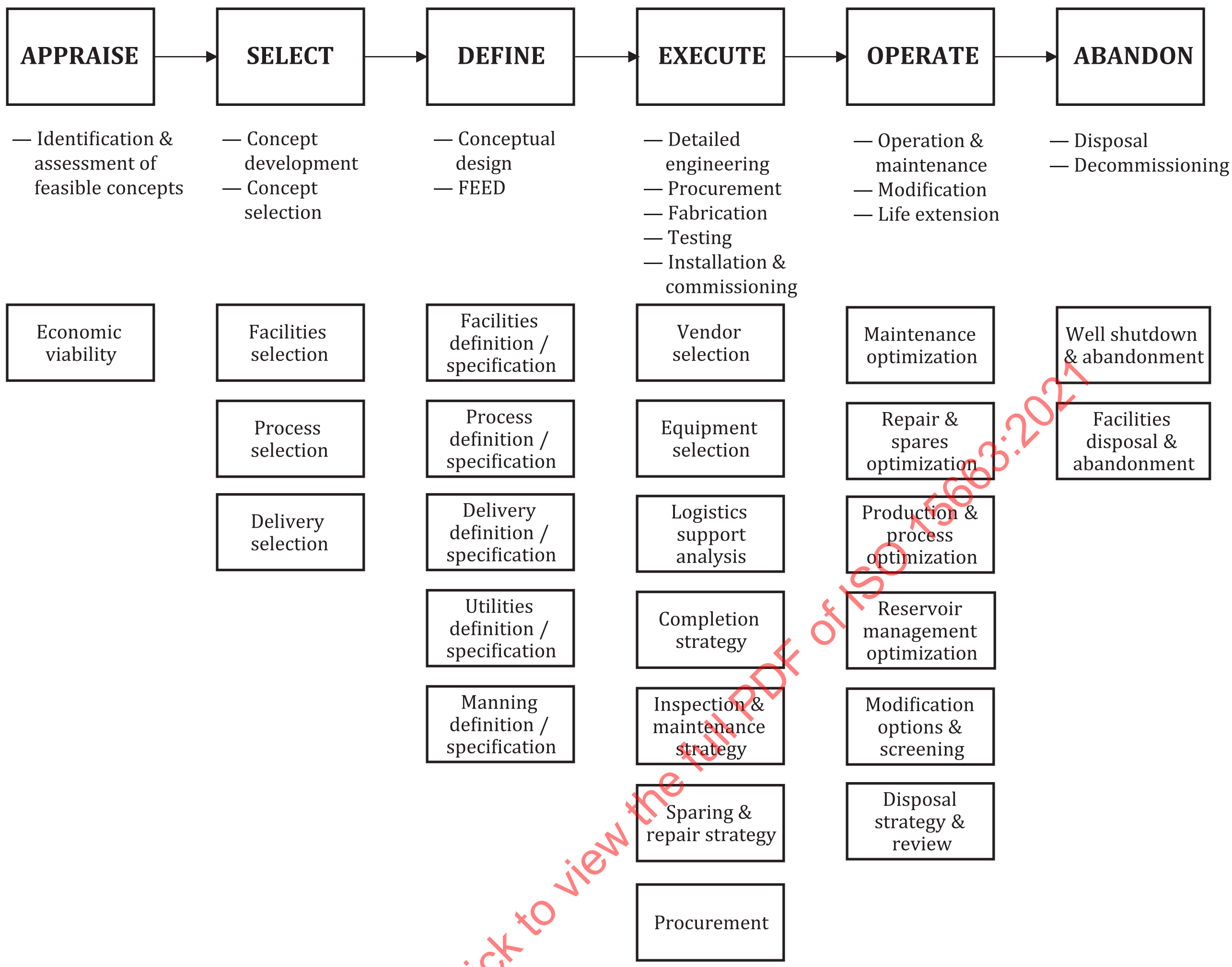


Figure B.1 — Life cycle phases and typical processes

When life cycle costing is integrated across the entire project life cycle, in each phase the foreseeable studies and the focus area for the next phase should be established.

The selection of life cycle costing measures depends on the item under consideration and on which phase or iteration the project has entered. When the first iterations of the life cycle costing process are undertaken during the life cycle phases ‘Appraise’ or ‘Select’, the object investigated may be the field development itself or the development concept. The revenue stream in total can be dedicated to this object, and all the traditional economic evaluation methods can therefore be applied.

For the further iterations in later phases, the concept may be broken down into the individual systems and further into equipment units. For these iterations, the revenue usually cannot be related to the object under consideration. The LCC measures can then be applied. Through minimizing the LCC of an asset or a function, where impact on the revenue stream of failures occurring are considered as a cost, asset value can be maximized in a consistent manner.

For these later iterations, economic evaluation measures such as NPV and IRR (see C.6.3.3) can be applied when evaluating additional CAPEX resulting in reduced OPEX. The difference between the options of making the investment or not can then be considered as an investment appraisal evaluation.

Often, only the difference between competing options can be evaluated. In practice the possible economic evaluation measures are then reduced to NPV or LCC, since the other measures listed in Clause C.6 are calculated from the total cost and revenue stream associated with the decision.

B.2 Appraise

B.2.1 Scope of work

The scope of this phase normally includes identification of feasible concepts and gross comparisons of the major technical options. The focus is on the major cost and revenue trade-offs with minimum detail.

B.2.2 Contributions

In the life cycle phase 'Appraise', the main contribution of participating team is in supplementing the operator's expertise so that either a broader range of feasible concepts can be identified and assessed, or by providing information that allows high level comparison or screening of concepts.

B.2.3 Life cycle costing activities

Providing high level support to other functions in the organization based on life cycle costing models, competence or lessons learned existing from previous relevant development projects.

B.3 Select

B.3.1 Scope of work

In this phase, alternative technical and operational solutions are normally examined and compared, aiming at selecting a preferred concept. Processing and delivery are considered as well as procurement options (lease or buy) and the options for operation and support. The work normally includes examining and comparing alternative technical solutions. The focus is on the major cost and revenue trade-offs with minimum detail.

B.3.2 Contributions

This stage is normally undertaken by the operator in conjunction with a contractor who will help evaluate concepts within an accelerated procurement programme or within an alliance framework. Vendor contributions are likely to be limited to advice on major packages.

The main contribution of the participating team is in supplementing the operator's expertise so that either a broader range of concepts can be examined, or information is provided that allows concepts to be compared at the same level of definition. This is likely to be particularly true where new or novel concepts are proposed; input from contractors and vendors can reduce uncertainty for these options.

B.3.3 Life cycle costing activities

Potentially, the work can be undertaken by a team supplemented by contractors, vendors and consultants. In general, external support should be selected based on capability, competence and track record.

For projects where the extent of life cycle costing is large and involves many contributors, at the start of the life cycle phase 'Select', appointing a dedicated life cycle costing function or coordinator with responsibility for developing the life cycle costing strategy should be considered. Usually, the functional ownership would belong to the operator. Considerations in developing the strategy include ensuring that life cycle costing contributes towards the development of the engineering and design, support and contract strategies; in practice this requires discussion and agreement from other internal functions and partners to achieve buy-in.

The planning of life cycle costing activities and the work to be done for the 'Select' life cycle phase and the subsequent life cycle phases should also be carefully considered. Recommended content of an LCCMP is provided in A.1.2.

Where multiple contractors have been asked to make proposals for the most suitable concept or solution for a specified development as part of a design competition, it may be appropriate to specify that any bid be supported by life cycle cost information. The cost headings can be specified together with the data sources and estimating process to be used. It should be ensured that bids can be compared on an equal basis and all-important costs have been included.

B.4 Define

B.4.1 Scope of work

The scope of this phase typically includes the identification and examination of the technical options for facilities, processes and delivery leading to a defined (matured) preferred concept or technical solution for FID.

Sizing and scoping the required utilities (e.g. power generation, accommodation, water supply and logistic support) and examining the cost trade-offs between facilities/processes and utilities are also within the scope of this stage. Life cycle costing activity stops when a preferred solution is identified, it does not attempt to optimize the solution. Overall layout, weight and dimensions are normally fixed on completion of the life cycle phase 'Define'.

B.4.2 Contributions

This stage is normally undertaken by the operator in conjunction with a contractor who will evaluate the technical options. Vendors' contributions are likely to add significant value with their specialist knowledge of the cost and performance of alternative options.

B.4.3 Life cycle costing activities

The life cycle costing work undertaken during the life cycle phase 'Define' will include the identification of a preferred option together with a corresponding outline engineering and design, support and contracting strategy, all culminating in a requirement specification. This will define the content of the LCCMP during this stage. It is at the beginning of this phase that the process of making decisions on competing equipment options normally starts.

For life cycle costing the principal objective in this phase is to evaluate alternative methods of meeting specific functional requirements and not to optimize the defined system solution. An important feature of the life cycle costing activities in the 'Define' life cycle phase is to stop the evaluation work as soon as a preferred concept or solution is found to a specific functional requirement instead of trying to optimize that concept or solution.

For example, if LCC analysis during the 'Select' life cycle phase identified the provision of water to the platform as an issue (either a risk item or cost driver), then work in the life cycle phase 'Define' concludes when waste heat evaporation is identified as the solution. It will then be the objective of life cycle costing activities during the life cycle phase 'Execute' to develop and optimize the waste heat evaporation solution.

The work will require input from operator, contractor and vendor, irrespective of the contractual arrangements. The operator's contribution is the provision of operating and support experience and data. It is likely that the contractor will undertake the majority of the work, and the vendor can assist in the definition and evaluation of specific systems within their area of expertise.

B.5 Execute

B.5.1 Scope of work

The life cycle phase 'Execute' typically includes system engineering, detailed engineering, procurement, fabrication, testing, installation and commissioning. The life cycle costing scope of work will include system and equipment optimization within constraints defined during the life cycle phase 'Define', and also support to change control and project managers assessing the impact of concessions to the relevant economic evaluation measures.

B.5.2 Contributions

The contractor's role should be to provide the system definition, maintain the overall facility configuration and deal with integration issues. The vendor is often best placed to undertake the majority of life cycle costing activity at this stage and should respond to functional specifications provided by the contractor.

The majority of work at the construction, hook-up and commissioning stage is likely to be undertaken by contractors. Vendors should assist in evaluating the impact of installation changes on the performance predicted for their equipment.

During the 'Execute' life cycle phase the operator has a supporting role in the provision of in-house operating and support data.

B.5.3 Life cycle costing activities

During the life cycle phase 'Execute', life cycle costing is concerned with optimization of the system solutions selected during the 'Define' life cycle phase. It is probable that the majority of LCC will arise from a small number of processes and this is where effort should be concentrated. It is these processes that offer the greatest potential for added value.

The vendor should be best placed for the optimization work in the life cycle phase 'Execute', with assistance from the contractor. The contractor's primary focus should be integration issues at the facility level including operations and maintenance strategy. There is a mutual dependence between the contractor and vendor at the system boundaries.

The vendor contribution to life cycle costing activities is dependent on their life cycle costing capability and the contractor might need to supply life cycle costing assistance in some cases. Vendors of critical systems are likely to have been involved in earlier phases. Where appropriate, life cycle costing expertise should be one of the criteria used in vendor selection.

During this phase, careful evaluation of the selection of items which might have a low unit cost and would typically be considered as "bulk" items should be considered. Due to their prevalence and potential impact on maintenance loading, many of these items could contribute significantly to the LCC of maintaining an asset and in many cases also contribute to lost production costs. Vendors can often provide information regarding the potential impact of their products on LCC.

One method of addressing this situation is to rank equipment according to the following items:

— business value;

— number of units installed;

— production unavailability contribution.

The lead candidates from each ranking criterion should be followed up and the systems optimized. The rankings can also be used to make judgements on how many items to be subjected to life cycle costing and focus the attention to equipment where life cycle costing is likely to have most benefit.

Where equipment has a high initial value, life cycle costing can reduce costs to the minimum consistent with the required duty. Equipment with low initial value can also be significant if there are a large number of units installed. Items such as compression fittings do not represent a large proportion of the CAPEX, but can if they are of poor quality, lead to lost revenue, high downtime and significant replacement costs. The third criterion is impact on production availability. From production availability studies or based on previous experience, a ranking of the main production unavailability contributors can be provided.

The major challenge for the contractor is to obtain commitment from the vendors to minimize life cycle cost, particularly where optimization leads to a lower cost procurement solution, i.e. how to reward the vendor for improved NPV. A potential solution is to increase the vendors' overall revenue by extension of their role, both into earlier (preferred supplier) and later phases (support). This issue is discussed in Clause A.3.

It is at the life cycle phase ‘Execute’ that difficulties with lack of input data to support life cycle costing will become most apparent. System level optimization requires more detailed operating and support cost data and where a contractual commitment to support is required, increased uncertainty will lead to higher risk premiums and higher prices. It is in the operator’s interest to make operations and support data accessible to all who have a need to know. Deficiencies found can be translated into requirements placed on the data collection systems established during the operating and support phase (see ISO 14224:2016).

There are a number of challenges in selecting vendors on a life cycle cost basis, including but not limited to:

— each vendor could have collected data on equipment performance in a different way;

— the performance of the equipment can be different in the proposed application;

— the sample data on which performance predictions are made may be very small (e.g. also if operational experience with new technology is yet limited).

In the majority of cases, this means that data uncertainty is high if proposals from different vendors are being compared. This should be considered in any analysis. The uncertainty is reduced if alternative equipment from the same vendor is being compared. The most effective approach is to select vendors on their equipment range and their life cycle costing capability, and then work with them after order placement to optimize the equipment delivered for the specified application.

Regarding the construction, hook-up and commissioning stages, life cycle costing in is primarily a policing activity, examining concession and change proposals to determine their impact on overall profitability. As there are likely to be a large number of minor concessions, some form of filtering or screening is required to minimize unnecessary effort. Procedures should be established to scrutinize minor concessions at the equipment level to ensure they do not result in significant impact at the facility level. Major problems encountered that result in schedule impact should be subject to life cycle costing assessment to examine the trade-offs between rectification options, time and revenue.

B.6 Operate

B.6.1 Scope of work

The work of this phase will include support for a wide range of studies covering all facets of facility operation and support. Modifications to the facility may also involve LCC analysis. Similarly, life cycle costing is also applicable to life extension studies. If major modifications are involved, this will require reference to the issues considered above under the life cycle phases ‘Select’, ‘Define’ and ‘Execute’.

B.6.2 Contributions

The work is carried out by a mix of operators, contractors and vendors depending on the scope of work, contractual arrangements (who is responsible for operations and support) and the subject matter being examined.

An important contribution of life cycle costing is to provide reliable information to future projects and activities. Besides, the availability of operating history and expert judgment can make life cycle costing activities much easier in this phase compared to the previous phases.

B.6.3 Life cycle costing activities

Strategies for operation and maintenance are initiated in the life cycle phase 'Select' and developed and implemented in subsequent life cycle phases. During the life cycle phase 'Operate', the role of life cycle costing is to optimize these strategies and assist with the examination of change which can arise from:

— problems such as obsolescence;

— changes in production rates, water cuts or gas fraction requiring modification;

— improved extraction techniques or new tiebacks that provide life extension opportunities;

— proposed cost improvement initiatives in areas such as maintenance optimization, condition monitoring and sparing strategies;

— expiry of in-service support contracts, leading to a need to re-evaluate, negotiate and potentially compete.

In all cases, the project cycle is repeated, going through the phases of 'Select', 'Define', 'Execute', etc. The cycle may be accelerated, but in the majority of cases the change can be anticipated and planned in advance.

Where support is contracted out, rewards may be tied to incentive schemes and life cycle costing can assist in valuing and defining the incentives. In addition, life cycle costing in operations may take on broader responsibilities associated with the provision of information to future activities. The availability of operating history and expert judgement can make life cycle costing during the 'Operate' life cycle phase easier than in other life cycle phases.

When comparing life extension options, it is necessary to align cost drivers with the output from life time extension studies as described in ISO 20815:2018, Clause I.24. Asset-specific data is crucial to the application of life cycle costing for life extension decisions. So, planning the necessary data collection is required well in advance of the actual LCC analysis.

B.7 Abandon

B.7.1 Scope of work

The work in this phase will typically include examination of when and how to decommission and dispose of all, or part, of the asset.

B.7.2 Contributions

The work is likely to be carried out by the operator in conjunction with specialist contractors.

While the options relevant for the 'Abandon' life cycle phase have been considered early in the project development, there are differences between these options which will influence the economic evaluation measures used in the trade-off analysis. Notwithstanding, considering these options in life cycle costing will prevent cost surprises at the end of the asset's life.

B.7.3 Life cycle costing activities

The work carried out at earlier life cycle phases will have considered the options in this life cycle phase. A basic disposal plan should have been agreed during the 'Define' life cycle phase, but timing, schedule and final strategy should be decided in the light of actual production experience. The generic options are:

— decommission the facility and dispose;

— re-use the facility in whole or in part;

— sell on the asset (facility and field) as a going concern prior to the end of field life.

It is also possible that these options are assessed against options to extend operating life. In comparing these options, there are timing differences between the first two and sale of the asset. Where asset sale is considered, life cycle costing can be used to investigate the cost, revenue and time trade-offs.

Where decommission and disposal is preferred, the life cycle costing techniques for evaluating disposal options are based on selection of the best practical environmental option considering cost, safety and the environment.

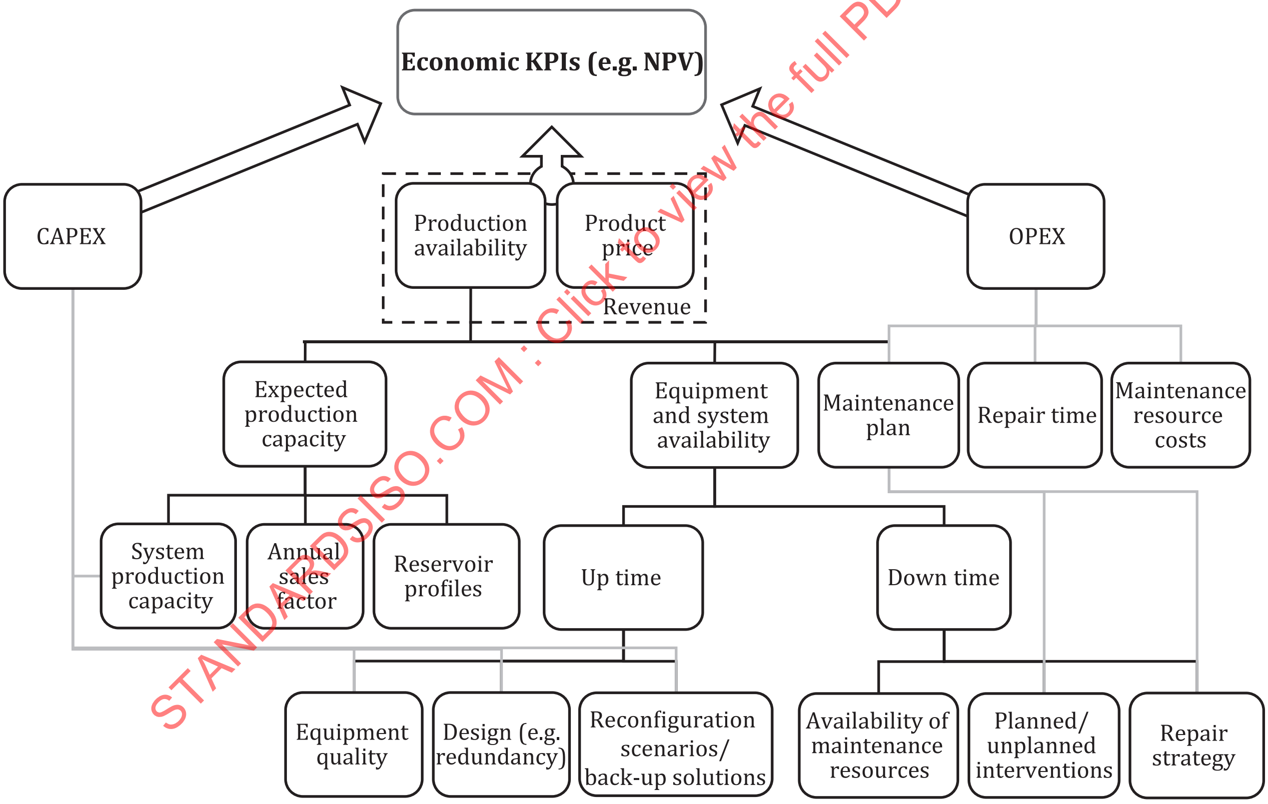
Annex C
(normative)

Life cycle costing techniques

C.1 General

This annex provides further requirements and information regarding life cycle costing techniques whereof some or several are to be applied when undertaking life cycle costing assessments. Such assessments are applicable for comparison purposes and may give input to the overall project economic analysis.

Figure C.1 shows relationships between the three main elements of life cycle costing, i.e. CAPEX, OPEX and revenue factors (REVENUES or LOSTREV), for which estimation requires various quantitative analysis techniques that are described in Clauses C.2, C.3 and C.4. Figure C.2 illustrates examples of trade-off considerations to minimize LCC and to create value for the relevant stakeholders. The economic value creation is achieved by balancing cost and revenue, not by purely addressing cost.



Key

—— revenue factors

—— cost factors

NOTE This is a reproduction of ISO 20815:2018, Figure 2.

Figure C.1 — Business model: Influence factors of production assurance on project economy

Quality checking (validation) of CAPEX and OPEX cost data, with respect to economics as well as technical and operational basis, is addressed in Annex D. Uncertainty considerations with respect to CAPEX and OPEX cost data are addressed in Clause C.7. For quality checking of revenue loss (e.g. production unavailability) reference is also made to ISO 20815:2018.

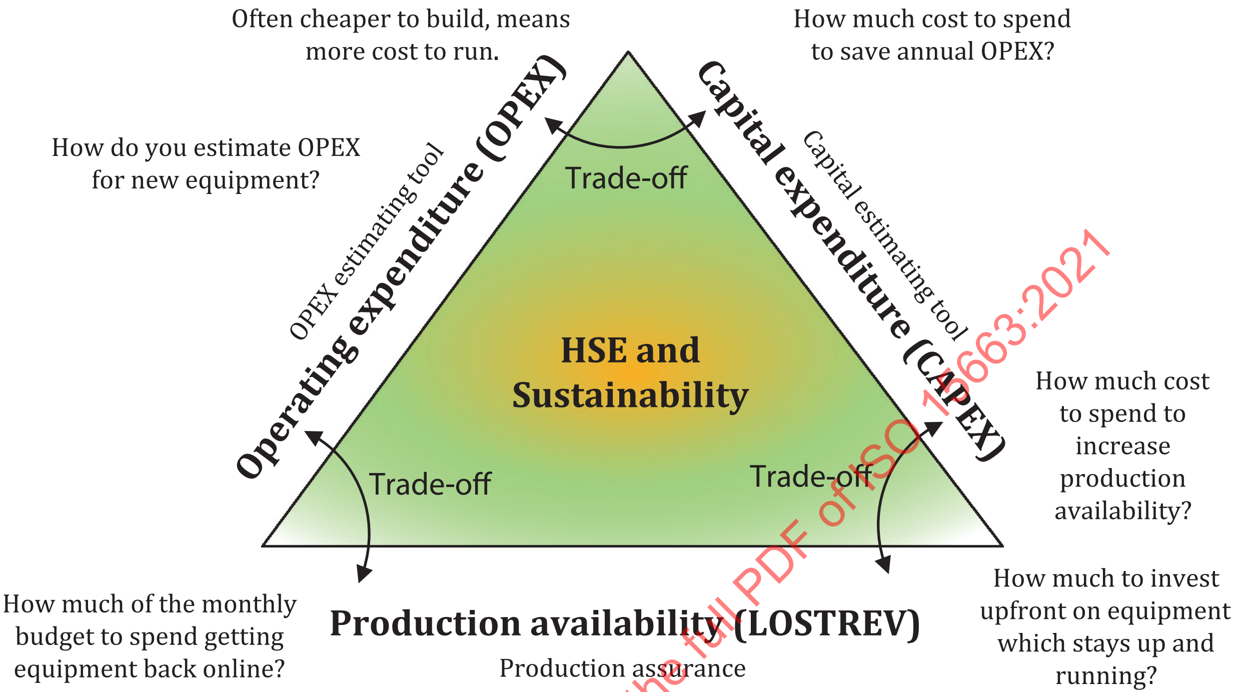


Figure C.2 — Examples of trade-off considerations to minimize LCC

C.2 CAPEX

C.2.1 General

When evaluating the CAPEX elements in a life cycle costing process, it is of major importance to utilize and evaluate cost data in a stringent and consistent manner. The CAPEX cost elements shall have concise definition and content to make the comparison of CAPEX cost elements possible and relevant. The level of detail shall be decided and adapted to the life cycle phase and the subject matter for the life cycle costing comparison. Using cost data in a consistent manner across the competing options is of vital importance to build quality into the results. The comparison should also include ranges of uncertainty for the cost elements relevant for the various life cycle phases of the project.

In order to develop a consistent cost breakdown structure, ISO 19008:2016 shall be considered when classifying these agreed costs. This classification of cost is based on three primary facets (i.e. resources – COR, asset breakdown – PBS, and activity breakdown – SAB) that can be used to categorize cost information in a consistent manner.

Examples of CAPEX cost elements are:

— management cost;

— engineering cost;

— equipment and material cost;

— construction cost;

— transportation cost;

— installation cost;

— commissioning cost;

— operational readiness cost;

— modifications cost (e.g. due to facility extension, subsea tie-ins);

— decommissioning cost.

In estimations for LCC comparison, the allocation of cost between CAPEX and OPEX may require developing clear criteria in accordance with company governance rules.

Depending on the life cycle costing subject matter, management cost should identify the allocation for the different companies and stakeholders involved.

C.2.2 Technical and operational basis

The use of CAPEX cost data for the technical facilities and relevant operational assumptions will depend on the technology and design, system configuration and equipment quality, etc. This implies that the CAPEX cost data shall reflect the level of technical knowledge on such matters and details shall be selected and adapted to the life cycle phase. For example, equipment with high quality (i.e. higher reliability) can have higher CAPEX, but lower OPEX. The use of sensitivity analyses in a life cycle costing analysis can reveal differences and be beneficial for the decision support.

The operational issues can impact the CAPEX cost elements, but will in a larger degree affect the OPEX cost elements.

C.2.3 Decommissioning

Decommissioning can also be considered as a separate project when the actual need for decommissioning comes in the life cycle phase 'Abandon' (see Clause B.7) and can then be regarded as CAPEX at a more detailed level than when (and if) decommissioning was part of the life cycle cost estimation in the early stages of the life cycle.

Examples of CAPEX cost elements for decommissioning projects are:

— management cost;

— survey cost;

— care and maintenance cost;

— engineering cost;

— demolition cost;

— transportation cost;

— site restoration cost;

— scrap handling cost.

See further information in Reference [23].

C.2.4 DRILLEX

DRILLEX can also require attention in life cycle costing and will then normally be part of the CAPEX element. Some drilling expenditures can also be part of the OPEX element, depending on the degree of simultaneous drilling (or workover) and production. This requires careful consideration and, depending on the subject matter for which life cycle costing techniques will be applied, can vary.

Examples of DRILLEX cost elements are:

— exploration well drilling cost;

— appraisal well drilling cost;

— production/Injection well drilling cost;

— well completion cost;

— well intervention cost;

— rig move cost;

— well abandonment cost.

ISO 19008:2016 also provides guidance on how drilling and well related costs are covered.

The drilling expenditures which occur in the operating phase related to well construction (e.g. planned or unplanned reservoir interventions, planned or unplanned downhole well interventions) shall be considered in terms of whether they are to be regarded CAPEX or OPEX. For example, if a side-track in an existing well is made to increase production, this can be subject to life cycle costing to justify such an operation.

C.3 OPEX

C.3.1 General

When evaluating the OPEX element in a life cycle costing process, it is of major importance to utilize and evaluate cost data in a stringent and consistent manner. The OPEX cost elements shall have concise definition and content to make the comparison of OPEX cost elements both possible and relevant. The level of detail shall be decided and adapted to the life cycle phase and the subject matter for the life cycle costing comparison. Using cost data in a consistent manner across the competing options is of vital importance to build quality into the results. The comparison should also include ranges of uncertainty for the OPEX cost elements relevant for the various life cycle phases of the project.

Examples of OPEX cost elements are:

— operations man-hour cost;

— cost of consumables (e.g. chemicals and fuel);

— cost of logistics;

— energy consumption cost;

— insurance cost;

— maintenance cost (see also maintenance categorization in ISO 14224:2016, 9.6.2);

— planned maintenance cost (preventive maintenance cost);

— unplanned maintenance cost (corrective maintenance cost).

— modifications cost (e.g. due to major equipment failures).

In estimation for LCC comparison, the allocation of cost between CAPEX or OPEX may require developing clear criteria in accordance with company governance rules.

C.3.2 Technical and operational basis

The use of OPEX cost data for the technical facilities and operational assumptions will as for CAPEX depend on the technology and design, system configuration and equipment quality (reliability and availability), but will also depend on e.g. integrity management, maintenance plan, repair strategy and weather influences as in the examples below.

— The equipment reliability performance will influence the OPEX cost data depending on, e.g. the facility, location (downhole, subsea, remote, onshore), repair strategy and maintenance resources. Life cycle costing can utilize information from production assurance analysis (e.g. production availability analysis, system availability analysis and equipment reliability analysis).

— Spare parts (capital spares, operational spares) will also represent a part of the OPEX cost elements in conjunction with life cycle costing. The amount of spare parts will depend on a spare part evaluation (see ISO 20815:2018, Annex I) and the underlying rate of failure. Such spare part evaluation can be used in conjunction with life cycle costing.

This implies that the OPEX cost data shall reflect the level of knowledge on such matters and details shall be decided and adapted to the life cycle phase. For example, equipment with high quality (i.e. higher reliability) can have lower OPEX, but higher CAPEX. The use of sensitivity analyses in an LCC analysis can reveal differences and be beneficial for the decision support.

The operational issues will impact the OPEX cost elements, but can also be reflected to some extent in the CAPEX cost elements.

C.4 Revenue factors (REVENUES or LOSTREV)

C.4.1 General

When LOSTREV is used instead of full revenues for each competitive option, the LOSTREV element shall be broken down into cost elements in a different way than CAPEX and OPEX, but will still require concise definition and content. The revenue loss will typically be volume-based measure which depend on how production capacity (which is a function of e.g. design and redundancies), reservoir profiles, etc. varies between the competing options (alternatives). Revenue loss can also reflect cost when time losses occur (due to aborted or delayed operations) and will then be a time-based measure.

Production assurance prediction is a key analysis technique for establishing the LOSTREV input to life cycle costing analyses. The lost production volume from a production availability analysis (or e.g. lost drilling time from a drilling rig availability analysis) shall be transferred and expressed into economic terms. The uncertainty should also reflect the life cycle stage when the estimate is given and life cycle period of production (production profile) being used.

Examples of LOSTREV elements are:

— cost of lost production — planned shutdown;

— cost of lost production — unplanned shutdown;

— cost of lost operating time (e.g. lost drilling time, lost intervention time);

— contractual penalties;

— lost deliveries;

— tax credit/debit.

ISO 20815:2018, Clause I.19 gives further guidance on how to present production availability predictions for use in conjunction with life cycle costing. There should be interaction between production assurance activities and LCC analysis. The production availability for the selected option used in the LCC analysis can act as tentative production assurance requirement (see also ISO 20815:2018, Clause B.1).

An overview of cost and revenue factors to be considered in conjunction with the economic optimization is shown in Figure C.1. These factors can be used to better prioritize and understand the production assurance activities with respect to life cycle cost elements (i.e. CAPEX, OPEX, REVENUES and LOSTREV).

C.4.2 Technical and operational basis

The LOSTREV cost data shall also reflect the level of technical knowledge on such matters and details shall be decided and adapted to the life cycle phase. For example, technical facilities with high equipment quality (i.e. higher reliability) will have lower production unavailability (implies higher REVENUES or lower LOSTREV) and lower OPEX, but higher CAPEX. The use of sensitivity analyses in an LCC analysis can reveal differences and be beneficial for the decision support.

The estimation of this LCC cost element, i.e. the lost revenue estimation, can be made by:

— simplified guesstimates;

— model-based estimation by use of production assurance and reliability management activities that already might have been undertaken or can be done for the life cycle costing subject matter (see C.4.3).

C.4.3 Production assurance and reliability management activities

In the process of life cycle costing, the production assurance and reliability activities address the aspects of operation and can provide a basis for establishing the cost of sustaining a function over its lifetime.

The following analysis, methods and techniques can be relevant for providing input to revenue loss estimates (and for OPEX estimates) in conjunction with life cycle costing:

— production availability calculations (see ISO 20815:2018, Clause I.5);

— system availability or equipment availability analysis (see ISO 20815:2018, Clauses I.4 and I.5);

— failure mode effect and criticality analysis (see ISO 20815:2018, Clause I.2);

— reliability-centred maintenance analysis (see ISO 20815:2018, Clause I.14);

— risk-based inspection analysis (see ISO 20815:2018, Clause I.15);

— test interval optimization (see ISO 20815:2018, Clause I.16);

— spare parts optimization (see ISO 20815:2018, Clause I.17);

— life cycle cost analysis (ISO 20815:2018, Clause I.19 reflects interaction with this document);

— life time extension analysis (see ISO 20815:2018, Clause I.24).

C.5 Value engineering and function analysis

Value engineering and function analysis are techniques, which are particularly useful for the identification of potential options and cost drivers (see 6.2 and 6.3).

Value engineering techniques study the cost and added value of each part of a system and compare added values with required costs. Subsequently, it provides a method for reducing costs and improving value.

Function analysis is a technique used to identify and understand the needs of the project, product or service. Function analysis supports creative problem solving by moving the focus away from the expected solution and placing the focus on the required performance or need.

By a systematic approach, the functions of a process or design are analysed to improve performance (e.g. safety, quality and reliability) and reduce life cycle cost. By proper definition of the functions, it is possible to create additional options with alternative solutions.

The technique focuses on the high-cost functions for the identification of options. It is important to include all relevant stakeholders in such studies. Each study can be structured as follows:

— information;

— function analysis;

— creation of additional options;

— evaluation of options;

— development of selected options.

In function analysis, a multi-disciplinary team establishes the main functions of the design and then establishes the sub-functions for the main functions. The equipment items for each sub-function are then identified and evaluated by the team. Option evaluation is normally carried out by iteration to ensure that evaluation does not affect the identification of options. Initial evaluation is carried out with a first screening on a qualitative basis. Remaining options after the first screening are evaluated and developed by undertaking the methodology of life cycle costing (see Clause 6).

See further information in EN 12973:2020 and ASTM E1699-14:2020.

C.6 Life cycle costing and economic model

C.6.1 General

Step 3 (analysis and modelling) of the life cycle costing process is described in 6.4. In most cases, a spreadsheet model represents the most cost-efficient and flexible solution for analysing competing options. There are instances where more complex models are appropriate, for example:

— for spares modelling at system or equipment level, the optimization process aims at balancing the cost of holding spares against the probability and cost of spare part shortage (see ISO 20815:2018, Clause I.17);

— for maintenance assessment studies at system or equipment level involving multiple operating, repair and stores locations;

— for detailed manpower assessment studies examining staffing, skills and resource requirements.

In such cases, proprietary LCC models may be used, or special high-level model or sub-level model may be developed specific to the application.

In constructing life cycle costing and economic models for specific applications, the following issues should be considered:

a) all cost data: how they will be normalized to a fixed economic base year;

b) inflation, discount rates, prices and exchange rates provided by corporate competent functions to be applied;

c) removal of non-appropriate overhead rates;

d) checking of manpower cost rates to ensure they reflect marginal cost of employment, so that fixed costs are treated appropriately;

e) identification and isolation of taxes and credits;

f) identification and exclusion of committed costs;

g) expenditure and revenue profiles to be applied.

When developing a specific LCC model, the need for subsequent sensitivity analysis and further iterations shall be considered. In particular, wherever possible, the parameters that will be varied in sensitivity analysis should be anticipated and the model organized such that changes can be made through single changes to the data (e.g. the ability to vary all CAPEX cost elements by a set percentage).

When further options are identified, it is inevitable that compromises will be made to accommodate these options which may include features not previously anticipated. A well-structured LCC model will reduce the probability of computational errors and too high uncertainty in results when these compromises are made.

The planning of LCC analysis and documentation of an LCC analysis report can also benefit from the guidance given in ISO 20815:2018, Annex D.

See also Reference [22] for further information regarding financial theory.

C.6.2 Discounting and other modelling aspects

C.6.2.1 Discounting

Discounting is a technique for converting different cash flows appearing at different points in time to comparable amounts at a specified point in time. The period used for discounting (monthly, quarterly, annual) shall be determined, taking into consideration the need to compare options (see C.6.2.2).

An amount of money today is worth more than the same amount of money received in the future, i.e. money has a time value. Income and costs related to different activities at different points in time during the life cycle should be compared on an equal basis. All future incomes and costs for each year in the life cycle are discounted to the value today. After the cash flows are discounted, the different alternatives are evaluated from the sum of these as if all incomes and costs happened at the same point in time.

The model should discount future costs and revenues back to today's value.

The general formula for discounting to present time a future cash flow at time t is mathematically expressed in Formula (C.1):

$$N_{\mathrm{PV}} = \frac{F_t}{(1+d)^t} \tag{C.1}$$

where

N_{PV} is the net present value (NPV);

F_t is the net cash flow at time period t (cash inflow minus cash outflow);

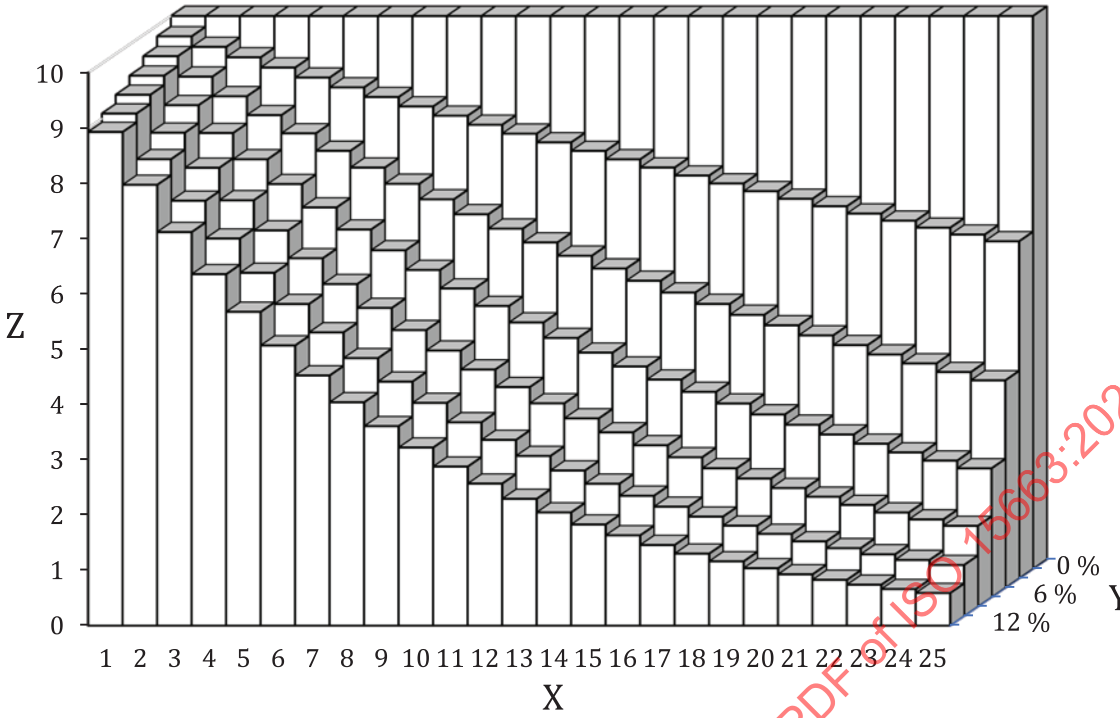
t is the time period (e.g. t=3 to represent year 3);

d is the discount rate.

C.6.2.2 Discount rate

The discount rate is the rate used in discounted cash flow analysis to determine the current value of future cash flows. The discount rate used determines how costs during operation are balanced against the investment.

Figures C.3 and C.4 show the effect of using different discount rates for balancing an annual constant OPEX of 10 million MU over 25 years against an initial investment of 120 million MU occurring 2 years before start of operation.



Key

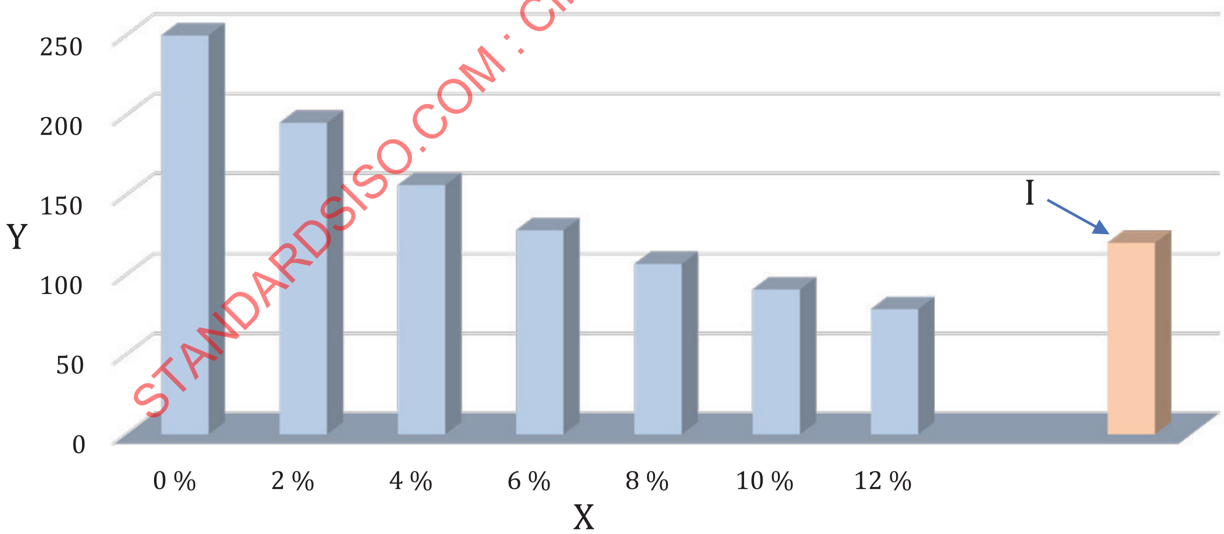
X year

Y discount rate

Z value, i.e. present value of OPEX

Figure C.3 — Effect of discount rate on OPEX over time

Figure C.3 shows how the discounted OPEX develops during operation with different discount rates.



Key

X discount rate

Y NPV

I initial investment

Figure C.4 — Effect of discount rate on weighing of OPEX

Figure C.4 shows the discounted sum of OPEX over the lifetime against the initial investment. At a rate of 12 % the OPEX is only 50 % of the initial investment, while at a rate of 0 % it is more than double the initial investment. This illustrates the importance in use of the discount rate.

Other factors that can impact the economic calculations are inflation and taxation. It should be considered whether to include inflation or not, and if calculations should be pre-tax or after-tax, in accordance with the company competent functions.

Inflation may be accounted using nominal method and real method:

— The nominal method principle is to discount yearly cash flows (costs and REVENUES/LOSTREV), which contain the effect of the yearly inflation (i.e. nominal cash flows), using nominal discount rate. Nominal discount rate is used for discounting a nominal cash flow that includes inflation.

— The real method principle is to discount yearly cash flows, that do not contain the effect of inflation (i.e. real cash flows), using real discount rate. The real discount rate is calculated, as a simplification valid when inflation rate is low, as the nominal rate less inflation (e.g. if nominal rate is 6 % and the inflation is constant at 2 %, the real rate is 4 %). Real discount rate is used for discounting a real cash flow that does not include inflation.

In normal practice, the nominal method principle is preferred, since the real method principle is easily calculated only when the inflation is constant in each year of the time period under consideration.

The implications of the fiscal regime should be evaluated. Ranking of alternatives can be altered by pre-tax/after-tax calculations dependent on tax regime. For the larger decisions, after-tax calculations are normal. For the smaller technical decisions, pre-tax calculations are normally sufficient, provided it is in line with corporate methods. When calculating after-tax, the cash flow should be adjusted for inflation and the discounting nominal rates.

C.6.2.3 Life cycle costing evaluation levels and tools

The evaluation methods to be used throughout the field development should be established at the start of the project to ensure consistency throughout the project. The main levels of life cycle costing evaluations are:

1) simplified calculation and discounting models;

2) discounting models;

3) economic assessment.

For most small project decisions, the first two are sufficient, provided they are aligned with corporate methods. Most technical decisions are very small. They are often not considered to be formal decisions, but everything done in relation to design has economic consequences.

Tools available range from simulation models to simple discounting. The selection of tools should be based on the individual needs of the problems being investigated. For most cases, a tailor-made spreadsheet model is easily developed and more than sufficient for the problem at hand. The ease of auditing and tracing the calculation flow should be considered.

C.6.2.4 Analysis and evaluation

When performing an analysis, the focus should be on:

a) identifying the design difference between alternatives and their economic impact;

b) identifying the cost drivers and seeking to reduce these;

c) involving discipline engineers to qualify input and results;

d) evaluating sensitivity of the results towards the input parameters;

The key is to keep life cycle costing as uncomplicated as possible.

The reason for analysis and evaluation being split into separate tasks apart from sensitivity analysis is to emphasize the need to check the results when they are first produced. The results should not be taken at face value.

The output from the analysis will be a ranking of the options in accordance with the economic evaluation measures specified, and a summary of the life cycle cost or the life cycle cost differences, identifying the cost drivers.

Evaluation of the analysis consists of checking the differences and finding out why they occur, if they are logical and can be explained. In addition, the total cost picture is checked to see if it is in accordance with expectations.

C.6.3 Economic evaluation measures

C.6.3.1 General

This subclause provides a basic knowledge of economic evaluation measures to functions involved in life cycle costing, in order to better understand the results of the evaluation as performed in accordance to corporate competent functions methods. Therefore, the general methods described are not intended as instructions of how an economic model with calculation and economic scenarios should be built and utilized.

The assumptions (e.g. technical and operational basis) for the cost elements shall be defined for use in the calculations.

The following should be applied in the life cycle costing model:

a) the agreed economic evaluation measures should be aligned with corporate governance methods;

b) the items selected for sensitivity analysis (see Clause C.7) should be identified.

Alternative simplified economic evaluation methods can be applied in the life cycle costing process. However, the individual methods should be applied in a manner consistent with corporate policy and criteria.

The weaknesses of the alternative methods applied should be taken into account. The decision rules of the individual methods (applied for the project specific LCC analysis of competing options) may not be mixed with the corporate decision criteria (used in project and company economics, see Figure 1).

The methods are usually developed with a set of assumptions and the decision rules that work only within that framework.

The following economic evaluation measures are described in the subsequent subclauses:

— net present value (NPV);

— life cycle cost (LCC);

— internal rate of return (IRR);

— profitability index (PI);

— payback period;

— break-even volume;

— break-even price;

— capital efficiency index (CEI).

EXAMPLE When applying NPV in a normal situation with limited amount of capital for investment, a ranking of options with positive NPV is required and a decision is needed taking into account other company policies, such as impact on HSE and sustainability (see 4.3.2, 4.3.3, and Clause C.7).

C.6.3.2 Net present value

The net present value (see 3.1.30) is applied to evaluate the desirability of an investment. NPV is calculated using Formula (C.2) or Formula (C.3):

$$N_{PV} = F_0 + \frac{F_1}{(1+d)} + \frac{F_2}{(1+d)^2} + \frac{F_3}{(1+d)^3} + \ldots + \frac{F_n}{(1+d)^n} \tag{C.2}$$

or

$$N_{PV} = \sum_{t=0}^{n} \frac{F_t}{(1+d)^t} \tag{C.3}$$

where

N_{PV} is the net present value (NPV);

F_t is the net cash flow at time period t (net cash flow is the algebraic sum for each time period of cash inflow minus cash outflow);

F_0 represents the net cash flow at time t=0 (i.e. when the decision is taken for initial investment, see 3.1.20);

t is the time period (e.g. t=3 to represent year 3);

d is the discount rate;

n is the number of time periods (e.g. n=20 to represent a lifetime of 20 years).

The NPV of a project is derived from discounting the net cash receipt at a discount rate which reflects the value of the required rate of return or alternative use of the investment funds or WACC, summing them over the lifetime of the project. The time of initial investment (t=0) should be the point in time when the decision is taken.

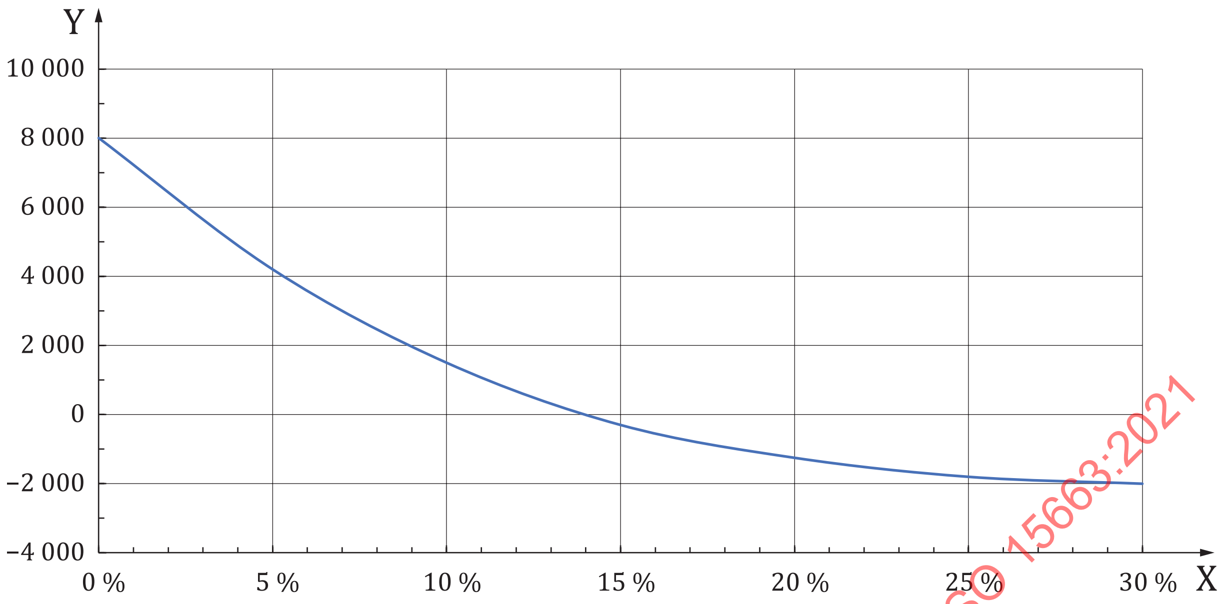
The decision rule associated with the NPV method is as follows:

— if NPV is positive, the project gives a positive return on investment and can be accepted;

— if NPV is negative, the project gives a negative return on investment and can be rejected.

For investment analysis, the discount rate represents the organization's requirement for return on investment for that specific level of risk. Weighted average cost of capital is normally applied. This rate is the weighted average of interest rate on external capital (loans) and required return on equity.

The NPV of a project depends on the discount rate applied. This can be visualized as an NPV profile as illustrated in Figure C.5.



Key

X discount rate

Y NPV

Figure C.5 — NPV as a function of discount rate applied (NPV profile)

C.6.3.3 Life cycle cost

The measure of life cycle cost (see 3.1.24) is applied for ranking the desirability of options when any particular of the revenue stream cannot be related to the objects under evaluation. Through minimizing the total cost of an asset or of a function, where impact on the revenue stream is taken into account as a cost (by including lost revenue as an element in the evaluation), asset value can be maximized in a consistent manner. LCC calculations are therefore applied to align technical decisions with corporate objectives.

The formula for discounting to be applied is the same as for calculating NPV [see Formulas (C.2) and (C.3)]. Different assumptions can be applied, and LCC is therefore defined as a separate measure.

LCC is the discounted sum of:

— CAPEX;

— OPEX;

— LOSTREV.

CAPEX should cover the relevant investment from discovery through appraisal, engineering, construction and commissioning including modifications until normal operations are achieved. See also Clause C.2, which includes examples of CAPEX elements.

OPEX should cover the relevant costs over the lifetime of operating and maintaining the asset. See also Clause C.3, which includes examples of OPEX elements.

LOSTREV (lost revenue reflecting revenue impact) should cover the relevant impact on the revenue stream from planned and unplanned events leading to production shutdowns, planned shutdowns and penalties, etc. Only effects from the specific asset or system alone should be considered. See also Clause C.4.

Decommissioning cost should cover relevant costs of abandonment of the asset, if there will be such a cost difference between alternatives evaluated. See also C.2.3, which includes examples of decommissioning (CAPEX) elements.

The elements to be included and calculated, should reflect the level of detail necessary for providing robust decision support.

Sunk cost, which are not relevant for the decisions to be made, should not be included in the calculations.

C.6.3.4 Internal rate of return

Internal rate of return (see 3.1.21) is another time-discounted measure of investment desirability as mathematically expressed in Formula (C.4):

$$N_{\mathrm{PV}} = \sum_{t=0}^{n} \frac{F_t}{\left(1+d_{\mathrm{R}}\right)^t} = 0 \qquad \text{(C.4)}$$

where

N_{PV} is the net present value (NPV);

F_t is the net cash flow at time period t;

d_{R} is the internal rate of return (IRR);

t is the time period (e.g. t=3 to represent year 3);

n is the number of time periods (e.g. n=20 to represent a lifetime of 20 years).

IRR shows how high the requirement for return on investment can be for the project to be still profitable. It finds the expected return on investment in the project.

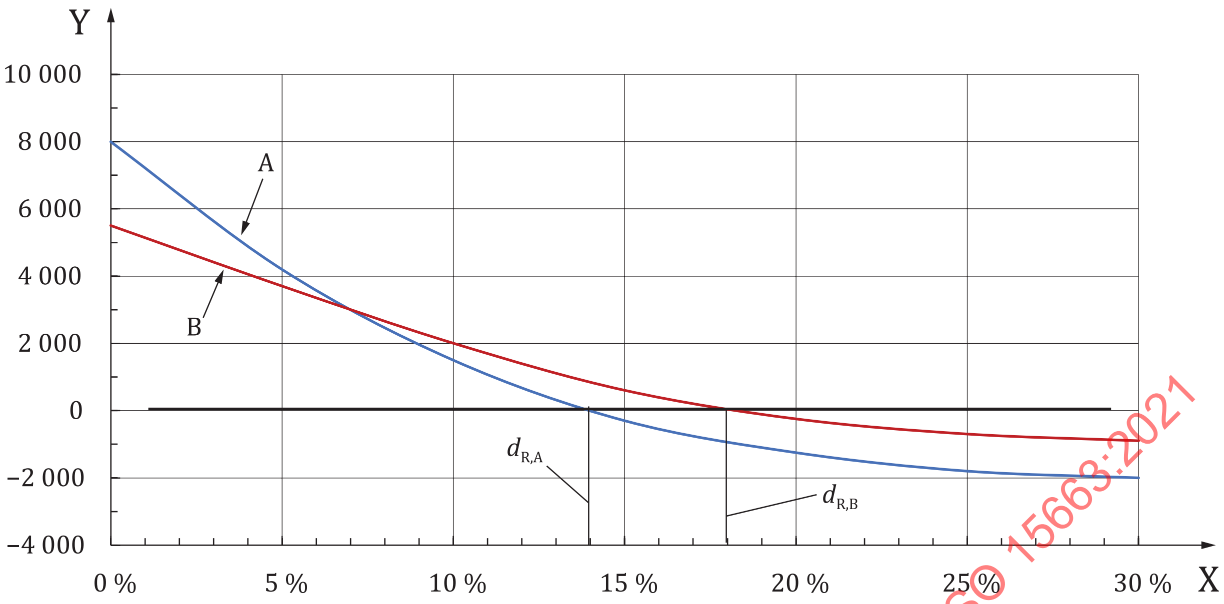
The decision rules associated with the IRR method are as follows:

— when IRR exceeds the discount rate, the project gives a higher return on investment than the required minimum and can be accepted;

— when IRR is less than the discount rate, the project gives a lower return on investment than the required minimum and can be rejected.

The normal decision rule is that an option which requires additional capital should only be selected if the IRR is greater than the hurdle rate or discount rate specified in the acceptance criteria.

The method of IRR is closely related to NPV. However, the methods can give different results when evaluating options against each other. This is visualized from two investment alternatives, represented as NPV profiles in Figure C.6.



Key

X discount rate

Y NPV

A competing option A

B competing option B

$d_{R,A}$ IRR for competing option A

$d_{R,B}$ IRR for competing option B

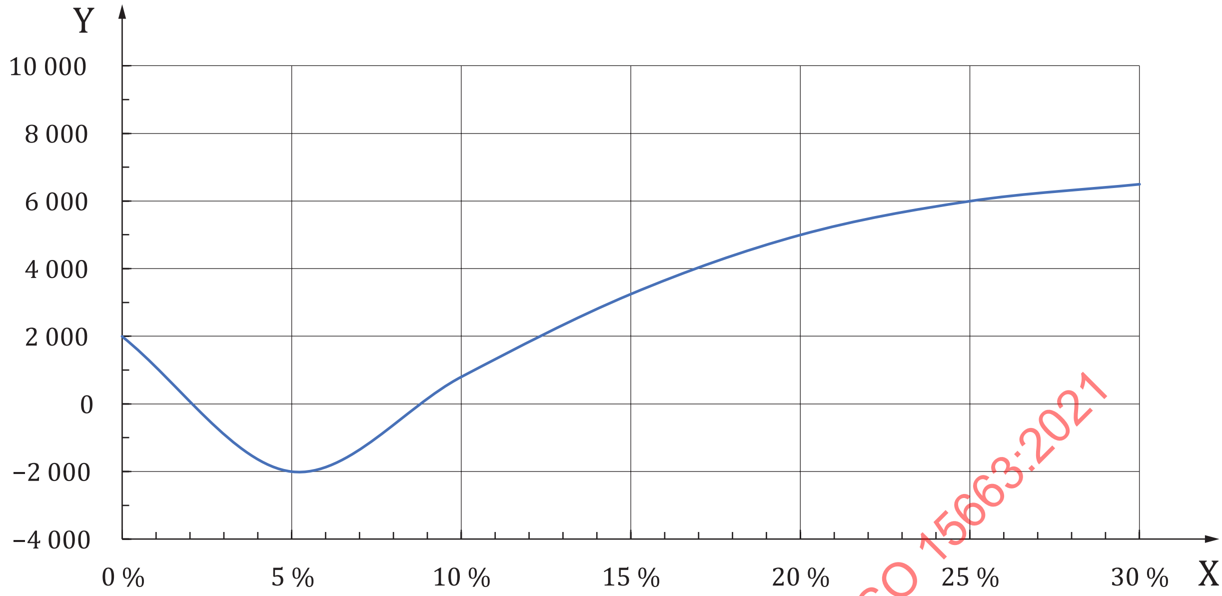
Figure C.6 — NPV profiles of two alternative investments

From this representation of investment alternatives, it can be derived that:

— NPV can give a different ranking of alternatives than IRR, depending on the discount rate;

— NPV can give a different ranking of alternatives by using different discount rates if the pattern of the cash flow varies.

A project that has a net cash flow that fluctuates between positive and negative will have several IRR. The NPV profile will cross the axis at zero several times as illustrated in Figure C.7. Where there are several rates of return, this economic evaluation measure is not a good basis for decision.



Key

X discount rate

Y NPV

Figure C.7 — NPV profiles of a cash flow fluctuating between positive and negative

C.6.3.5 Profitability index

A variant of the economic evaluation measure NPV is the profitability index (see 3.1.35).

The PI is defined as the NPV of the project divided by the discounted CAPEX, as given in Formula (C.5):

$$I_P = \frac{N_{PV}}{C_{PV}} \tag{C.5}$$

where

I_P is the profitability index (PI);

N_{PV} is the net present value (NPV);

C_{PV} is the present value of CAPEX (discounted).

In the case of independent projects, the PI and the NPV economic evaluation measures yield the same acceptance/rejection decision. PI can be an efficient economic evaluation measure for prioritizing of alternatives if there are bottlenecks.

C.6.3.6 Payback period

The payback period (see 3.1.32) is a simple method for determining a project's desirability, based on the number of years required to recover the investment from the project's future cash flows, see Formula (C.6).

$$Y_{PB} = Y_2 - Y_1 \tag{C.6}$$

where

Y_{PB} is the payback period;

Y_2 is the year in which the cumulative sum of net cash flow is greater than zero;

Y_1 is the year in which income starts.

When the cash flow fluctuates over time, the payback period is calculated by summing the cash flow until the year in which the cumulative cash flow become positive and the investment is covered.

C.6.3.7 Break-even volume

The break-even volume (see 3.1.4) is the production volume or any volume that generates income, where revenues and costs balance, i.e. where $N_{PV} = 0$.

The most common application is determination of minimum sales volume required for generating positive net revenue.

C.6.3.8 Break-even price

Break-even price (see 3.1.3) is typically expressed in break-even price per unit quantity of production (e.g. volume, weight, energy), depending on the main product (e.g. oil, gas or the combined break-even price per oil equivalent, LNG, petrochemical products).

For oil and gas, differentials for the given quality of the product should be reflected in the break-even calculations to make it comparable with the market price. Oil and gas differentials are quality and transportation price differences between the product from the project and the market price.

When combined break-even price is made, then the conversion factors used for the calculation shall be documented, since such conversion factors can vary depending on the main and associated products.

For example, as given in Formula (C.7), cost per standard barrel of oil is a method for determining the lowest realized oil price (not market price) a field development project can withstand and still cover all its life cycle cost.

$$U_{PV} = \frac{(C_{PV} + O_{PV})}{Q_{PV}} \quad \text{(C.7)}$$

where

U_{PV} is the break-even price as the present value of the cost per standard barrel of oil;

C_{PV} is the present value of CAPEX (discounted);

O_{PV} is the present value of OPEX (discounted);

Q_{PV} is the present value of the expected total production (discounted).

CAPEX and OPEX represent the discounted total cost of investments and operation for the project's life cycle. Expected total production represents the discounted production according to the economic lifetime.

The method of cost per standard barrel of oil can provide a measure of the robustness of options, but is insufficient to determine which option is expected to be most profitable.

C.6.3.9 Capital efficiency index

Capital efficiency index (see 3.1.6) can be calculated to illustrate the value creation relative to capital exposure. CEI is similar, but somewhat different than PI. PI is used to rank project/option when invested CAPEX is the bottleneck by calculating the project that gives the highest value per invested unit, while CEI does the same but has the negative cash flow after tax as the bottleneck. CEI is given as NPV of project after tax divided by the absolute value of the NPV of cash flow after tax until the point where annual cash flow becomes positive. As long as there are constraints, there will be a need to prioritize between investments. CEI can be used to measure value creation relative to capital constraints.

The CEI, as mathematically expressed in Formula (C.8), is defined as the NPV of the project divided by the absolute value of the NPV of cash flow after tax until the point where annual cash flow becomes positive, that is:

$$I_{CE} = \frac{N_{PV}}{|F_{PV}|} \tag{C.8}$$

where

I_{CE} is the capital efficiency index (CEI);

N_{PV} is the net present value (NPV);

$|F_{PV}|$ is the absolute value of the net present value of cash flow after tax until the point where annual cash flow becomes positive.

C.7 Environmental aspects

This clause provides some additional guidance with respect to life cycle costing, when environmental aspects are part of all or some of the competing options.

Guidance on cost-benefit analyses to assess environmental damage costs and environmental benefits are described in ISO 14007:2019, 7.1.2, and cover all type of environmental aspects (see ISO 14001:2015, 3.2.2).

The principles of life cycle costing will also apply to such subject matters.

Abatement cost (see 3.1.1) can be part of life cycle costing to cover environmental aspects. Avoided/removed CO_2 emissions is the most usual parameter to calculate abatement cost, but the methodology can vary and can also be used for other avoided/removed emissions such as NO_x, oil in water or chemicals. In order to compare the abatement cost of different options, the abatement unit cost (e.g. cost per weight or volume of emissions) can be utilized as performance indicator.

The abatement unit cost is calculated as the NPV of the abatement cost (excluding saved fees and taxes for the avoided emission, e.g. CO_2 taxes) divided by the discounted amount of the avoided/removed emission quantity (e.g. tonne). The discount rate used for avoided/removed emissions is the same as used for the calculation of economic measures (e.g. NPV). As discount rate may vary, the discount rate used shall be documented if such calculation is done as part of life cycle costing.

C.8 Considerations for uncertainty and sensitivity analysis

Having established that the initial results are reasonable, consideration of uncertainties and sensitivity analysis aim to provide the basis for reducing the number of options and improve confidence in those going forward, for implementation or for further evaluation.

Uncertainty shall be evaluated in relation to:

a) the input data;

b) the results;

c) the ranking of competing options.

In addressing how uncertainties can affect the estimates, the following input categories should be considered:

a) cost, such as manpower rates, equipment costs, overhaul cost;

b) technical factors, such as mean time to repair, failure rates, time between overhauls, production capacity, hydrocarbon field size;

c) project plan, such as time to first oil, production time scale;

d) economic factors, such prices, taxation, discount rate.

Further guidance on handling data uncertainty with respect to new technology is given in Clause D.5.

The uncertainty related to the value of the predicted input, with performances measure, can be analysed and, if possible, quantified. Variations in performance measures, for different time periods under defined framework conditions, and available statistical data are used to determine the variability of the inputs and to support the quantification of uncertainties and risks. The main factors causing this variability should be analysed and validation of the result is done by quantifying the uncertainty involved.

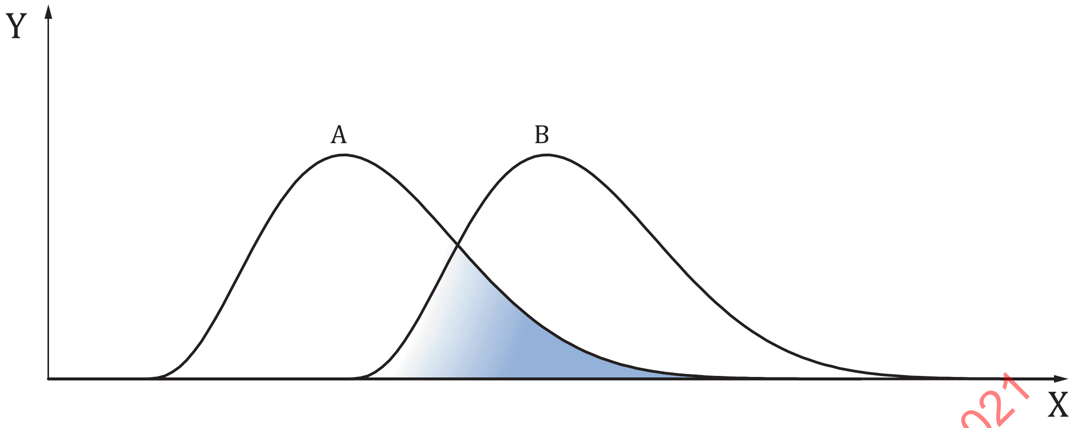
Sensitivity analyses should consider uncertainties in the most important input parameters, such as alternative assumptions, variations in production or costs, alternative system configurations.

Sensitivity analysis can be performed changing one input parameter at a time to see what effect this produces on the result, e.g. assuming a plus and minus percentage value from the most likely estimated value of the parameter or considering the effect of the parameter worst, base and best case.

The uncertainties and risks quantification can have the form of a probabilistic distribution for the input data or a measure of the spread of this distribution (e.g. type of distribution, standard deviation, prediction interval).

Stochastic sampling techniques are usually applied in LCC analysis, through industry tools, in determining the corresponding probability distribution and outcomes, like the mean values along with upper and lower bound (e.g. p10 and p90). These techniques are effectively applied to predict cost, schedule, reservoir production profiles, production availability, economics, etc.

A possible uncertainty probabilistic distribution result in life cycle cost comparison of two competing options is shown in Figure C.8. Option A has the lowest mean expected life cycle cost, but there is an overlap in the possible life cycle cost range distribution which indicates that option B could become better than option A.



Key

X life cycle cost

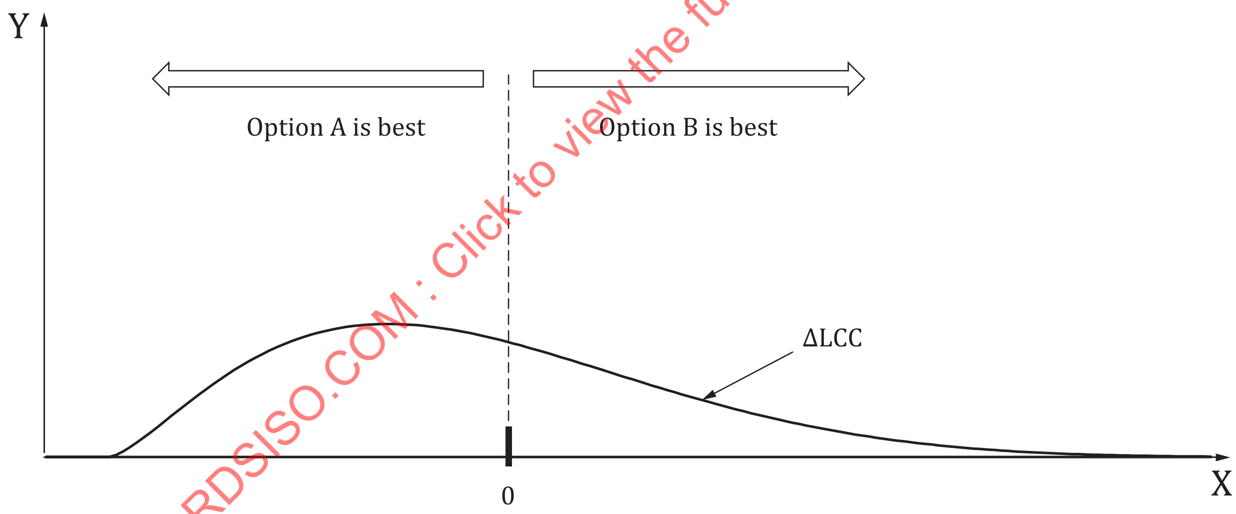
Y probability

A probabilistic distribution of LCC for competing option A

B probabilistic distribution of LCC for competing option B

Figure C.8 — Potential result range of competing options A and B

A picture of LCC for option A minus LCC for option B is shown in Figure C.9.



Key

X life cycle cost

Y probability

Δ LCC LCC_A - LCC_B

LCC_A LCC of competing option A

LCC_B LCC of competing option B

Figure C.9 — Possible range in difference in results, option A minus option B

When evaluating the range of possible results, this distribution can be derived by subtracting the result of option B from the result of option A. This difference between options can then be visualized against the probability of occurrence.

When LCC of option A minus LCC of option B is less than 0, then option A is best. Initially there could have been a relatively high probability of the opposite. When correlated uncertainty (affecting both results the same way and by the same magnitude) is taken into account this probability is significantly reduced, and the ranking can be qualified.

The overlap in the potential range of results of the competing options is evaluated in terms of the probability that the ranking of options could be reversed. When investigating which parameters lead to the uncertainty and neglecting those that give the same effect to all options, the overlap is reduced and the uncertainty in the results is decreased.

A simplified way to estimate the uncertainty in the results assumes that the cost and revenues elements are independent and normally distributed. The standard deviation is then calculated using Formula (C.9):

$$\sigma_T = \sqrt{\sum_{e=1}^{m} \sigma_e^2} \tag{C.9}$$

where

σ_T is the total standard deviation for the m cost elements;

σ_e is the standard deviation for cost element e.

When using Formula (C.9) after evaluating two competing options A and B and finding that A has the lowest LCC, the result is indicated reliable when the mathematical expression given in Formula (C.10) is fulfilled:

$$L_{CC,A} + \sigma_A < L_{CC,B} - \sigma_B \tag{C.10}$$

where

$L_{CC,A}$ is the life cycle cost of competing option A;

$L_{CC,B}$ is the life cycle cost of competing option B;

σ_A is the total standard deviation for the life cycle cost of competing option A;

σ_B is the total standard deviation for the life cycle cost of competing option B.

The approach outlined is only one example and gives a rough estimate. An example of how to use this approach is presented in Annex E.

The quality of the result is a reflection of the quality of the input data. The acceptable level of uncertainty is dependent on the objective of the life cycle costing.

Guidance on treatment of uncertainty in analyses is also provided in ISO 20815:2018, D.3.7.

Annex D
(informative)

Data input

D.1 General

This annex provides guidance on all aspects related to the establishment of data used in life cycle costing activities (see Step 2 in 6.3). Examples of cost elements to help the user in considering aspects of costs associated with CAPEX, OPEX and revenue factors (REVENUES or LOSTREV) are shown in Tables D.1, D.2, D.3, D.4 and D.5.

D.2 Data input framework

D.2.1 Technical and operational basis

The technical and operational basis provides an important framework and input for the LCC analysis and will be part of the reporting of the LCC analysis.

The key features of the competing options should be described, or documentation referenced for the technical and operational aspects that are considered to influence the results of the LCC analysis and that are required to identify the subject matters in the analysis.

Technical and operational basis will require information such as:

— description of the installation/plant;

— description of relevant equipment characteristics:

  — for equipment data common to any equipment class, see ISO 14224:2016, Table 5 for further information;

  — for equipment specific data, see associated tables in ISO 14224:2016, Annex A for relevant equipment classes.

— technical information related to the subject matters in the LCC analysis (e.g. design basis, piping and instrumentation diagrams and process flow diagrams);

— production profiles;

— operational and maintenance strategies.

The level of details for the technical and operational basis description will also depend on the associated cost data in the LCC analysis, which will be established (and documented) separately as described in D.2.2 to D.2.4.

D.2.2 Data related to cost elements and cost drivers

A key task within life cycle costing is to define the cost drivers, i.e. the major cost elements (see 6.3.2). The cost drivers vary depending on the subject matter and will require information accordingly.

The major cost elements are items within CAPEX, OPEX and LOSTREV. A cost driver can be one dominating cost element or a combination of cost elements. The aim is to identify the minimum number of cost drivers needed to discriminate between the competing options and to reduce the effort associated with the remaining cost elements.

For the purpose of establishing data input, it is important to consider topics such as:

— which cost elements are important for the comparison;

— how the costs are to be applied and calculated in the model;

— how sensitivity analysis will be accommodated, with focus on the cost elements and cost drivers;

— the sources of the data, access to data needed;

— data quality and confidence range of the data;

— time and efforts in compiling the data.

The focus with respect to data selection should be on the main differences between the competing options. Cost elements that are common for all alternative options can normally be excluded. Sunk costs, which are not relevant for the decisions to be made, should not be included in the calculations.

By having a systematic approach for establishing the data, and by using a defined cost breakdown structure, the user will obtain quality in the cost data and the LCC analysis.

Examples of cost elements to be evaluated as cost drivers are provided in the Tables D.1 to D.5. Guidance on information related to cost breakdown structure for associated cost elements is provided in D.2.4.

Table D.1 — Examples of CAPEX related cost elements

	Cost element [b]	Comments
General [a]	Management cost	
	Equipment cost	
	Material cost	
	Engineering cost	
	Construction cost	
	Transportation cost	
	Installation cost	
	Commissioning cost	
	Operational preparedness cost	Specify the relationship to OPEX
	Decommissioning cost	If life cycle costing is done in the life cycle phase 'Abandon', a sub-division of decommissioning cost may be required, see Table D.2.
	Drilling expenditures	If need for sub-division of drilling expenditures, c.f. Table D.3.

[a] See Clause C.2 for further information.

[b] If CAPEX cost elements are considered in accordance with ISO 19008:2016, cost elements will be expressed as cost items.

Table D.2 — Examples of decommissioning related cost elements

	Cost element	Comments
Decommissioning [a]	Management cost	
	Survey cost	
	Care and maintenance cost	
	Engineering cost	
	Demolition cost	Environmental requirements clean-up cost.
	Transportation cost	
	Site restoration cost	
	Scrap handling cost	Environmental requirements clean-up cost.

[a] See C.2.3 for further information.

Table D.3 — Examples of DRILLEX related cost elements

	Cost element	Comments
DRILLEX [a]	Exploration well drilling cost	
	Appraisal well drilling cost	
	Production/Injection well drilling cost	
	Well completion cost	
	Well intervention cost	The type of well intervention should be specified with respect to planned or unplanned reservoir related interventions, subsea well intervention, etc.
	Rig move cost	
	Well abandonment cost	Relationship to decommissioning cost need to be specified.

[a] See C.2.4 for further information.

Table D.4 — Examples of OPEX related cost elements

	Cost element	Comments
General [a]	Operations man-hour cost	
	Cost of consumables and spares	
	Cost of logistics	
	Energy consumption cost	
	Insurance cost	
	Maintenance cost - planned	
	Maintenance cost – unplanned [b]	Production availability, system availability and/or reliability analysis will provide information; see C.3.2 and C.4.3.

[a] See Clause C.3 for further information.

[b] Type of planned and unplanned maintenance activities are defined in ISO 14224:2016, 9.6.2, and should be considered when establishing data input.

Table D.5 — Examples of LOSTREV related cost elements

	Cost element	Comments
General [a]	Cost of lost production — planned shutdown [b]	Lost revenue.
	Cost of lost production — unplanned shutdown [b]	Lost revenue.
	Cost of lost operating time [c, d]	Lost drilling time, lost intervention time, etc.
	Contractual penalties	Such cost element will depend of the contractual framework and type of subject matter.
	Lost deliveries	The type of lost deliveries depends on the product and/or operation for which LCC analysis is performed and could differ from cost of lost production (planned/unplanned).
	Tax credit/ debit	This cost element will be needed depending on subject matter for which LCC analysis is done.

[a] See Clause C.4 for further information where the relationship to production availability, system availability and/or reliability analyses are given.

[b] Production loss categories are defined in ISO 20815:2018, Tables G.1, G.4, G.5 and G.6. ISO/TS 3250:—[1] also provides further details and format for production loss categorization.

[c] ISO 20815:2018, Table G.2 defines time loss for a drilling rig, and ISO 20815:2018, Table G.3 defines time loss for an upstream installation and intervention vessel.

[d] Special data considerations are needed for non-operator organizations.

D.2.3 Information needs for cost breakdown structure

The information needed for the establishment of the cost breakdown structure for life cycle costing should be adapted to the subject matter and the organizational capability of providing data.

All main cost elements should be considered, i.e. CAPEX, OPEX, and revenue factors (REVENUES or LOSTREV), as also shown in Tables D.1 to D.5.

The cost elements should be structured taking into account:

a) the way in which costs are acquired and recorded;

b) the way cost elements are calculated.

Cost data may be assembled on different levels of the applied taxonomy structure depending upon data availability and quality. Data may be gathered at the equipment class level on pumps, compressors, pressure vessels, etc. from previous projects or directly from vendors. Data may be collected at the section/system level (e.g. instrument air and chemical injection) or at the higher level of plant/unit, as in the case of replicating a previous installation or system.

ISO 14224:2016 has an example taxonomy classification system used for reliability and maintenance data for equipment, as shown in Figure D.1. ISO 14224:2016, Table A.3 provides a table of 97 systems within upstream, midstream, downstream and petrochemical business categories. ISO 20815:2018, Annex G provides a format for presenting production loss categories for lost revenues. ISO 19008:2016 has a classification system used for standard cost coding, where PBS and COR address taxonomic levels as in same Figure D.1. The use of these taxonomy coding structures in conjunction with life cycle costing should be considered. ISO 19008:2016 applies especially for CAPEX and OPEX data (see 6.3.2).

