

COMMON REQUIREMENTS

LIFE CYCLE COST

P-CR-002, Rev. 1, December 1994

1 FOREWORD

This standard has been developed by the NORSOK standardisation work group and agreed by the Norwegian industry for the widest possible national and international application.

Annex A, B and C are normative.

2 SCOPE

The scope of this standard is to standardize Life Cycle Cost calculation methods for system and equipment.

3 NORMATIVE REFERENCES

Norsok Offshore Standard P-DP-001 , Operational Principles.

4 DEFINITIONS AND ABBREVIATIONS

4.1 Definitions

System and Equipment Purchase Cost: The total purchase cost within a vendors scope of supply.

Installation Cost: The total cost to install the system and equipment within the vendors scope of supply.

Commissioning Cost: The total cost to commission, and where necessary certify, the installed system and equipment.

Insurance Spares Cost: The total purchase cost for the initial spares holding for the system and equipment within the vendors scope of supply, necessary to obtain the required system regularity.

Reinvestment Cost: The total cost to remove, refurbish or purchase, install and commission systems and equipment that is predicted to exceed its design life during the life of the production facility.

Manhour Cost: The total maintenance manhour cost required to maintain the system and equipment within the vendors scope of supply. The manhour cost to include preventive maintenance, servicing and corrective maintenance. The cost for corrective maintenance to include maintenance carried out offshore and maintenance carried out onshore.

Spare Part Consumption: The total cost of spare parts and consumables, over the design life of the system and equipment, necessary to complete the predicted work load for all maintenance actions (i.e. preventive maintenance, corrective maintenance and servicing).

Logistic Support Cost: The total logistic support cost predicted to be necessary to support the maintenance requirements for the system and equipment within the vendors scope of supply (e.g. supply boat, diving support vessel).

Energy Consumption Cost: The total energy consumption cost for the system and equipment within the vendors scope of supply. It shall include the cost of the fuel required to generate the power and associated CO2 tax.

Deferred Production Cost: The total cost of deferred production due to the probability of failure of system and equipment.

Baseline Cost: Baseline cost data, for comparison with vendor input, will be based on historic records for similar equipment within the vendors scope of supply.

Life Cycle Cost Design Optimisation and Evaluation Model: A computer model programmed in Excel. The model contains the formulas shown in clause 5.5 and the assumptions provided in annex A . The model is structured for input of variable data and calculation of results. It enables the user to evaluate and optimise system and equipment design and calculate the result based on Life Cycle Cost. The model also provides an option to take tax considerations into account.

This model is given on a diskette supplied with the standard. The diskette also contains a small model for simpler cost calculations.

4.2 Abbreviations

CDP

Cost of deferred production

CMM

Corrective maintenance manhours (annual average)

CMSP

Corrective maintenance spare parts (annual average consumption)

MTTR

Mean time to repair

PMM

Preventive maintenance manhours (annual average)

PMSP

Preventive maintenance spare parts (annual average consumption)

5 CALCULATION METHOD

5.1 General

This section defines the calculation method to complete Life Cycle Cost evaluation and optimisation for system and equipment.

The calculations are automated in the LCC-model attached to the standard on a diskette.

The diskette also contains a small model for quick cost calculations on a higher level.

5.2 Applications

The LCC model may be used for:

- Design Optimisation (Evaluating different system designs).
- Bid Evaluation.

5.3 Uncertainty

Qualification shall be accomplished by quantifying uncertainty in the results of the Life Cycle Cost evaluation.

5.4 Assumptions

To complete the Life Cycle Cost calculations within the model, assumptions shall be made. The necessary assumptions are shown in annex A .

5.5 Calculation Method

5.5.1 General

This section defines the calculations that provide the basis to complete Life Cycle Cost evaluation and optimisation, and the formulas required.

5.5.2 Value of Money Related to Time

The base year for the analysis shall be established. All costs shall be discounted back to this base year to take into account the time value of money. For this the following formula is applied:

$$\sum_{t=0}^n = \frac{S_t}{(1+k)^t}$$

Where:

S_t

Net cost in year t. This can be assumed equal for all the years, it can vary according to production, or it can have some other given variation throughout the lifetime.

n

The lifetime of the equipment/function to be evaluated. When the required lifetime of the equipment exceeds the expected lifetime, the required life is used.

k

The discount rate/interest rate to be used for the evaluation.

5.5.3 Capital Cost

Capital cost shall be calculated by adding the following cost elements:

- Equipment purchase cost.
- Installation cost.
- Commissioning cost.
- Insurance spares cost.
- Reinvestment cost.

Where there is a deviation between when the investments will be made and the base year for the evaluation, capital cost shall be discounted back to the base year as shown in clause 5.5.2.

5.5.4 Operating Cost

General

Operating cost shall be calculated by adding the following cost elements:

- Manhour cost.
- Spare parts consumption cost.
- Logistic support cost.
- Energy consumption cost.

For costs that will be constant through the lifetime, multiply the annual cost with a discount factor f to get the cost over the lifetime.

$$f = \frac{1}{(1+k)^{t_1-t_0}} \sum_{t=t_1}^m \frac{1}{(1+k)^t}$$

Where:

t_0

The base year for the evaluation

t_1

The time for startup of operations

m

Number of years in operation

k

The discount rate/interest rate to be used for the evaluation.

a) Manhour Cost

Manhour cost shall be calculated as the sum of:

- Corrective maintenance manhours.
- Preventive maintenance manhours.
- Servicing manhours.

Corrective Maintenance

The formula for average annual corrective maintenance manhours (CMM) is as follows:

$$CMM = \lambda_T \cdot 8760 \cdot MTTR \cdot A \cdot M$$

Where:

CMM

Average annual manhour cost for corrective maintenance

λ_T

Total failure rate as number of failures per hour. This includes all failures. (Equals 1/Mean Time Between Failures)

8760

Number of hours in a year

MTTR

Mean Time To Repair. The time in hours it takes to repair the faulty item back to operating condition

A

The number of men required to do the work. This also includes the safety aspect.

M

The manhour rate

The average annual costs shall be discounted as shown in clause 5.5.2.

Preventive Maintenance

The formula for annual preventive maintenance manhours (PMM) is as follows:

$$\text{PMM} = \text{Number of times per year} \times \text{Manhours} \times \text{Manhour rate}$$

Where:

Manhours = The number of manhours required to perform the preventive maintenance routine

The average annual cost shall be discounted as shown in clause 5.5.2.

Servicing

Calculations shall be as for Preventive Maintenance.

b) Spare Parts Consumption

Spare parts consumption shall be calculated as the sum of:

- Spare parts for corrective maintenance.
- Spare parts for preventive maintenance.
- Spare parts for servicing.

Corrective Maintenance

The formula for average annual corrective maintenance spare parts (CMSP) consumption shall be as follows:

$$CMSP = \lambda_T \times 8760 \times \text{Average corrective spares}$$

Where:

CMSP

Average annual corrective maintenance spares consumption

λ_T

Total failure rate as number of failures per hour. This includes all failures. (Equals 1/Mean Time Between Failures)

8760

Number of hours in a year

Average annual spares = Average spares needed for repair of the equipment.

The average annual cost shall be discounted as shown in clause 5.5.2.

Preventive Maintenance

The formula for average annual preventive maintenance spare parts (PMSP) consumption is as follows:

PMSP = Number of times per year x Average spare parts consumption per PM routine

Servicing

Calculations shall be the same as for Preventive Maintenance.

c) Logistic support cost

Logistic support cost shall be calculated as the sum of all logistic support activities necessary to maintain the equipment.

The average annual cost shall be discounted as shown in clause 5.5.2.

d) Energy consumption cost

For an equipment package where the power requirement is constant throughout the lifetime and not dependent of the production the formula for average annual energy consumption cost is as follows:

Where:

$$EC = \sum_{i=0}^{100\%} \left[\frac{Q_i \cdot Q_l}{\mu_{tl} \cdot \dots \cdot \mu_{ln}} \right] \cdot C$$

Q_l

Power requirement at operational level l for the equipment requiring power (e.g. a pump)

O_l

Average fraction of time the equipment will be operated at operational level l.

l

Operational level in steps from 0 to 100% (Max required capacity)

μ_{ln}

Efficiency at operation level l for related equipment in the power transmission (i.e. gear, converter, el. motor)

C

Cost per kWh based on fuel consumption and CO₂ -tax

The average annual cost shall be discounted as shown in clause 5.5.2.

For an equipment package where the power requirement is varying throughout the lifetime, e.g. follows the production profile, the formula will be the same but will have to be calculated with different distributions $\{O_l\}$ for operational level for each year and be discounted.

5.5.5 Cost of Deferred production

The formula for cost of deferred production (CDP) is as follows:

$$CDP = E \times p \times D \times L \times C$$

Where:

CDP

Cost of Deferred Production

E

Average number of critical failures per year

p

Probability of production reduction

D

Duration of production reduction

L

Quantity of production loss per time unit

CDP

Cost of one hour downtime per year throughout the lifetime calculated as the difference in Net Present Value between a production profile with the simulated availability and one with one hour lower availability per year.

This is a general formula that can be adjusted to different configurations where:

$$E = \lambda_C \cdot 8760$$

Critical failure rate as number of failures per hour x Number of hours in a year

p

1 at configuration 1 x 100%

$$1 - e^{-(n-1) \cdot \lambda_{train} \cdot T}$$

at a configuration with n trains and one can go down without causing production reduction. T equals average total downtime for critical failures for the component evaluated.

L

Dependent on configuration and location in the system for the unit being evaluated.

CDP

Field dependent

5.5.6 Life Cycle Cost

Life Cycle Cost for the system and equipment to be evaluated equals the sum of the following cost elements:

- Capital Cost.
- Operating Cost.
- Cost of Deferred Production.

5.5.7 Uncertainty

The uncertainty of the calculations shall be assessed in relation to the confidence in input data.

To get an estimate of the uncertainty involved the cost elements can be assumed independent and Normal distributed. The standard deviation s can then be calculated as follows:

$$\sigma_T = \sqrt{\sum \sigma_e^2}$$

Where:

σ_T = The total standard deviation

σ_e = Standard deviation for cost element e

When using the above formula after evaluating two alternatives A and B and finding that A has the lowest Life Cycle Cost, the result is indicated reliable when:

$$LCC_A + \sigma_A < LCC_B - \sigma_B$$

ANNEX A

ASSUMPTIONS (Normative)

A THE FOLLOWING ASSUMPTIONS SHALL BE MADE AND BE INCLUDED IN THE MODEL PRIOR TO OPTIMISATION AND EVALUATION OF SYSTEM AND EQUIPMENT DESIGN

PARAMETER

VALUE

DENOM
INATION

COMMENTS

Fuel gas:

For power generation

CO2 tax

0,82

NOK/Sm3

Price of sales gas

NOK/Sm3

When gas sales contract is applicable

Price of transport

NOK/Sm3

When gas sales contract is applicable

Value of alternate use

NOK/Sm3

Equals price of sales gas minus cost of transport

Gas turbine efficiency

m3/MW Day

For power generation

Cost per kw hour

- CO2 tax

0,27

NOK/kwh

Calculated from CO2 tax per Sm3 and gas turbine efficiency

- Alternate use

NOK/kwh

Calculated from value of alternate use and gas turbine efficiency

- Total cost

NOK/kwh

Equals the sum of CO2 tax and alternate use

Diesel fuel:

Price

1,30

NOK/litre

- CO2 tax

0,82

NOK/litre

- Cost of diesel

2,12

NOK/litre

Equals the sum of CO2 tax and the cost of diesel

Manhour cost:

Offshore Manhour

NOK/hour

Onshore Manhour

NOK/hour

Logistic support cost:

ROV

NOK/day

Support vessel

NOK/day

Supply boat

NOK/day

Cost of deferred production

NOK/hour a year

See clause 5.6.5

Annual operating hours

Timing:

Base year

See clause 5.5.2

Investment year

See clause 5.5.3

Operation start-up

The year when production starts

Life of field

From start of production

Discounting:

Discount rate

%

Relevant rate supplied by the Operating Company

Discount factor

- Investment

Calculated as shown in clause 5.5.3

- Operating cost

ANNEX B

LIFE CYCLE COST MODEL

B LIFE CYCLE COST MODEL

LIFE CYCLE COST MODEL ([Excel file](#))

ANNEX C

USER GUIDE LCC MODEL

C USER GUIDE LCC MODEL

C.1 INTRODUCTION

C.1.1 Calculating LCC

LCC-calculations are done to aid a decision making process. In many cases it is not necessary to perform a complete LCC-analysis. It is often enough to estimate the differences between alternatives for the major cost elements. The LCC-model provides input functions/ cells for the different cost elements. You, as the user, can perform a complete analysis and generate reports or choose to use only some of them at an aggregated level.

The diskette also contains a small spreadsheet ([Excel file](#)) that can be used at an aggregated level for calculating the time value of money.

C.1.2 Description

The LCC-model (LCC.xlw) is made as a workbook in Excel 4.0. The workbook contains a spreadsheet and a hidden macro-file. The macro-file is the software (program) that controls and helps using the spreadsheet and should not be changed.

The spreadsheet is a protected document. This implicates that you are only allowed to enter values in the input cells. Formulas are then protected against accidental overwriting. If you want to change the content in a cell that are protected, you can unprotect the document and change the content in the cell. After doing this the document should be protected again.

C.1.3 Installation

For the model to be able to operate at an adequate speed, the workbook should be copied from the diskette to the hard disk. The name of the file is LCC.xlw .

The small spreadsheet for aggregated calculations, [Excel file](#) , should also be copied.

C.1.4 Adjustment to Screen

The spreadsheet is adjusted to a 17" screen. For other screen sizes it may be advantageous to adjust the zooming to fit the page to the screen.

Figure ([preview](#), [figure](#))

C.2 MAIN STRUCTURE

Based on the input data there will be generated a report that consists of:

LCC Summary

(Output form)

Life Cycle Cost Elements

(")

Capital Cost

(Input form)

Preventive Maintenance Cost

(")

Servicing Cost

(")

Corrective Maintenance Cost

(")

Logistic Support Cost

(")

Energy Consumption Cost

(")

Cost of Deferred Production

(")

Uncertainty in the Results

(Qualification form)

Basic Assumptions

(")

Calculation Method

(")

In addition there can be created a report that shows the cost elements for the different alternatives per year pre tax and after tax.

The above elements correspond to the buttons at the top of the spreadsheet and the different forms are thus found by clicking the respective button as shown below.

Figure ([preview](#), [figure](#))

C.2.1 Summary of Calculation Procedures

Use of the LCC-model contains the following steps:

1. Fill in the field and company specific data in the Assumptions form.
2. Fill in what is to be evaluated in the General Input form.
3. Fill in the rest (or relevant) cost element input forms.
4. Qualify the calculations through the following qualification forms; Assumptions, Uncertainty and Calculation.
5. The results are shown aggregated, per cost element and per year.
6. Print LCC-report or cost distribution over life.

C.3 INPUT OF DATA

All input data for the alternatives to be evaluated are entered into the relevant input form. There are eight different input forms. Field and company specific data like economic parameters and field life are entered in the form; Basic Assumptions.

C.3.1 General Input

The opening input window is shown in page 2. The window contains information on what is to be evaluated. Only the yellow fields shall be filled in.

Heading

Project, discipline and evaluating objects are written here. This will be the heading on each side of the report.

Alternatives to be Evaluated

Number of alternatives to be evaluated are entered through clicking the button and choosing from the dialogue box.

Figure ([preview](#), [figure](#))

The model allows for two or three alternatives. The names of the alternatives can also be entered.

Energy Consumption

Number of energy consuming units are entered by clicking the button and choosing from the dialogue box.

Figure ([preview](#), [figure](#))

The model allows for one to three different power consuming units. Then equipment information are entered.

Equipment

Here the different equipment/ units in the system/ equipment to be evaluated are listed.

The other evaluation alternatives like pre/ after tax calculations, discount rate and field life time are entered under Assumptions.

C.3.2 Capital Cost

Capital cost is split into the following cost elements:

- Equipment purchase cost.
- Installation cost.
- Commissioning cost.
- Insurance spares cost.
- Reinvestment cost.

For each element, the year when the expenditure occurs, have to be entered. The elements can be split into a lower (more detailed) level and entered with name and cost of the various items for the different alternatives.

Reinvestment cost is entered under capital cost, even though it is treated as an operating cost for tax calculations

C.3.3 Preventive Maintenance Cost

The equipment listed under General Input are shown as default equipment. This can be changed by overwriting. For each alternative, different maintenance activities associated with the equipment can be listed, such as maintenance intervals, workload in man-hours and spare part consumption. Man-hour rates are specified under assumptions.

C.3.4 Servicing Cost

Service cost is entered the same way as the preventive maintenance cost. Intervals between servicing activities are counted in weeks.

C.3.5 Corrective Maintenance Cost

Corrective maintenance cost is entered the same way as the preventive maintenance cost. Interval between failures are counted in years.

C.3.6 Logistic Support Cost

Logistic support cost covers:

- ROV
- Supply boat.
- Support vessel.

For each 3 different intervals with time period each time can be entered for the different alternatives. The unit costs are given under assumptions

C.3.7 Energy Consumption Cost

This cost element has up to three forms dependent on what number of power consuming units were specified under General Input.

Energy consumption can be specified as constant through the lifetime or as varying. This is done by clicking the button and choosing from the dialogue box.

Figure ([preview](#), [figure](#))

Constant

Yearly operating hours for this equipment must be entered.

For the different operation levels (denominated as percentages of maximum) the percentage of time the equipment is running at this levels are entered. This is to get a good representation of how the equipment efficiency curve fits to the operation. In the example shown below the equipment is run at 50% of max. for 25% of the time, at 70% for 50% of the time and at 100% for 25% of the time.

Figure ([preview](#), [figure](#))

For these levels power consumption is entered. There is a possibility to include efficiency losses i.e. in driver and transmission.

Varies over Time

For this table operating hours have to be filled in for each year. Average quantum per hour to be handled by the equipment will vary from year to year. For each alternative there are three columns to make it possible to get three points on the efficiency curves. The cells for **operation level as percentage of average quantum per hour and for percentage of operation at that level** must be filled in. One can choose to use only one column, but percentage of operation at level must then be 100% and operation level will then be the annual average.

The energy consumption forms are all the same. To switch between the forms press the button with the unit number. When the message shown below appears there are not specified that many power consuming units. To change this go to the General Input form.

Figure ([preview](#), [figure](#))

C.3.8 Cost of Deferred Production

The equipment given under General Input is listed, but can be altered. For the different equipment, impact on production is answered by Y/N. For the equipment with production impact configuration is chosen by clicking the respective button and selecting from the dialogue box.

Figure ([preview](#), [figure](#))

Further, the mean time between critical failures (MTBFc) and mean time to repair critical failures (MTTRc) are entered.

When evaluating alternatives with different configurations one can use different lines and fill in MTBFc and MTTRc only for the respective alternatives.

C.4 QUALIFICATION

C.4.1 Basic Assumptions

This form contains all the economic assumptions and field data.

For calculating the cost of energy the cost of fuel gas and the gas turbine efficiency must be entered.

Cost of deferred production is given as the cost of one hour downtime per year. This is found by calculating the difference between the Net Present Value of two slightly different production profiles.

Base year for evaluation is normally the present year. Life of field is from start of operation

Under option for calculation, clicking the alternatives button gives the choice of pre tax or after tax calculation.

Figure ([preview](#), [figure](#))

C.4.2 Uncertainty in the Results

In this form the uncertainty involved is calculated based on the assumption that the cost elements are independent and Normal distributed. Input is given as the relative standard deviation for the different cost elements, e.g. +/-10%.

C.4.3 Calculation Method

This form outlines the calculation method. See also the standard Common Requirements Life Cycle Cost

C.5 RESULTS

C.5.1 LCC Summary

The LCC Summary form shows the aggregated cost, delta LCC and relative cost distribution for the main cost elements:

- Capital cost.
- Operating cost.
- Cost of deferred production.

Aggregated main cost elements are a summary of the Life Cycle Cost Elements form.

Delta LCC sets the lowest cost among the alternatives to zero and show how much higher the other alternatives are. This is done for the main cost elements and for the total LCC.

Relative cost distribution shows the distribution of the main cost elements within the alternatives.

Deviation from the lowest LCC sets the lowest alternative to zero and shows the relative difference for the others. This is the main result number from the calculations.

Uncertainty

Based on the results from evaluating the uncertainty there will come up a message "Uncertainty involved is acceptable" if the lowest alternative plus its standard deviation is lower than the second best alternative minus its standard deviation. If this is not the case the message "Further investigation should be made to reduce the result range" will appear.

C.5.2 Life Cycle Cost Elements

This form shows the total cost and cost per year for the different cost elements.

For capital cost the cost per year equals the investment. If investments are done in the base year for evaluation, cost per year and total cost will be equal.

C.5.3 Costs Over the Years Evaluated

By clicking this button one gets access to a number of forms showing the cost elements per year pre tax and after tax for the different alternatives.

C.6 PRINTOUTS

C.6.1 Print Report

By pressing this button there will be printed a report corresponding to the forms in the model as shown in Appendix B.

C.6.2 Print Costs over Life

By pressing this button there will be printed a report of the different cost elements for the different alternatives for each year pre tax and after tax as shown in Appendix B.

C.7 PROBLEM SOLVING

C.7.1 Locked Cells

Figure ([preview](#), [figure](#))

Locked cells are not supposed to be changed. If this still is desirable it can be done through **Options / Unprotect document** . When the changes are done the document should be protected again through **Options / Protect document** . The spreadsheet is protected to ensure that formulas are not overwritten by accident.

C.7.2 Slow Operation

Due to the size of the model it can give a relatively long responding time. This can be improved by using a faster computer with a larger memory.

The smaller spreadsheet [Excel file](#) will operate much faster, but cannot handle detailed calculations like the big LCC-model.

C.7.3 Number not Shown

When the numbers are shown just as ##### this can be solved by expanding the column with. The document must then first be unprotected. Expanding too much can cause a problem when printing the reports.