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# Life cycle analysis and recycling of ductile iron pipes for water applications

*Coût du cycle de vie et recyclage des tuyaux en fonte ductile pour l'eau*



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# Foreword

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This document was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.



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# Life cycle analysis and recycling of ductile iron pipes for water applications

## 1 Scope

This document specifies the evaluation method of life cycle analysis of ductile iron pipes used for water applications as specified in ISO 2531 and ISO 16631.

Studies on economic and environmental impacts are important for utility decision-makers as they seek to balance budget concerns over immediate and long-term needs across acquisition, operations and maintenance, and planned end of life. For authorities and engineers designing pipeline systems, the life cycle cost analysis serves as a tool to study various scenarios to determine the right solution for site-specific conditions and community values, as well as to provide the necessary data to support those decisions.

Informative annexes are included in this document as a compilation of reference and consensual factors (pumping cost, leakage incident rate, etc.).

## 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 2531, *Ductile iron pipes, fittings, accessories and their joints for water applications*



## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2531 and the following 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**
**life cycle cost**
**LCC**
cost of an asset throughout its life cycle, while fulfilling the performance requirements

**3.2**
**acquisition cost**
all costs included in acquiring an asset by purchase/lease or construction procurement route, excluding costs during the occupation and use or end-of-life phases of the life cycle of the constructed asset

[SOURCE: ISO 15686-5:2017, 3.1.1]

**3.3**
**operation cost**
total running costs for water conveyance, including the pumping cost

Note 1 to entry: Operation costs could include rent, rates, insurances, energy and other environmental/regulatory inspection.

**3.4**
**maintenance cost**
total labour, material and other related costs incurred to maintain pipelines

**3.5**
**end of life cost or revenue**
total of costs or fee for disposing of an asset at the end of its *service life* (3.7) or interest period, including costs resulting from pipeline dismantling, waste disposal and revenue from material recovery

**3.6**
**period of analysis**
period of time over which *life cycle costs* (3.1) or whole-life costs are analysed

Note 1 to entry: The period of analysis is determined by the client.

[SOURCE: ISO 15686-5:2017, 3.3.6, modified — "life-cycle" has been replaced with "life cycle".]

**3.7**
**service life**
total life of pipelines in use from the point of construction to the end of life

**3.8**
**residual value**
value assigned to an asset at the end of the *period of analysis* (3.6)

[SOURCE: ISO 15686-5:2017, 3.3.8]



**3.9**
**discount rate**
factor or rate reflecting the time value of money that is used to convert cash flows occurring at different times to a common time



Note 1 to entry: This can be used to convert future values to present-day values and vice versa.

[SOURCE: ISO 15686-5:2017, 3.3.1]

**3.10**
**leakage incident rate**
number of pipe bodies' damages or water leak per unit length of pipeline

**3.11**
**nominal diameter**
**DN**
alphanumeric designation of size for components of a pipework system, which is used for reference purposes

[SOURCE: ISO 2531:2009, 3.20, modified — The term has been changed from "nominal size" to "nominal diameter"; Notes 1 and 2 to entry have been removed.]

# 4 Basic concept of life cycle cost

## 4.1 Definition of life cycle cost

The life cycle cost is calculated using Formula (1) as a sum of not only the acquisition cost but also total costs including the operation cost such as the electric power usage cost of the pump operation, the maintenance cost such as the leakage cost, and the end of life cost or revenue. Annex B shows scenarios of LCC with two different pipelines.

$$C_L = C_A + C_O + C_M + C_E \quad (1)$$

$C_L$ is the life cycle cost;

$C_A$ is the acquisition cost; it includes the pipe material cost, construction cost and designing/survey cost;

$C_O$ is the operation cost; it includes the pumping cost;

$C_M$ is the maintenance cost; it includes the leakage cost, repair cost, etc.;

$C_E$ is the end of life cost or revenue; it includes the disposal cost and benefit of recycling.

## 4.2 Calculation method

The life cycle cost is calculated using Formula (2) to (4) by totalizing all the costs in a period of analysis. Cost in the future is converted into a current value using a discount rate. In a case where the evaluation period is not just the same as multiples of the service life, the residual value is deducted from the life cycle cost.

Case 1 $t_n < t_m$

$$C_L = C_A + \sum_{t=1}^{t_n} \left( \frac{C_{O,t} + C_{M,t}}{(1+r)^t} \right) - \frac{C_A \times (t_m - t_n)/t_m}{(1+r)^{t_n}} \quad (2)$$



Case 2 $t_n = t_m$

$$C_L = C_A + \sum_{t=1}^{t_m} \left( \frac{C_{O,t} + C_{M,t}}{(1+r)^t} \right) + \frac{C_E}{(1+r)^{t_m}} \quad (3)$$



Case 3 $t_m < t_n < 2 \times t_m$

$$C_L = C_A + \frac{C_A}{(1+r)^{t_m}} + \sum_{t=1}^{t_n} \left( \frac{C_{O,t} + C_{M,t}}{(1+r)^t} \right) + \frac{C_E}{(1+r)^{t_m}} - \frac{C_A \times (2 \times t_m - t_n)/t_m}{(1+r)^{t_n}} \quad (4)$$

where

$C_L$ is the life cycle cost;

$t$ is the time in year;

$t_n$ is the period of analysis;

$t_m$ is the service life;

$C_A$ is the acquisition cost;

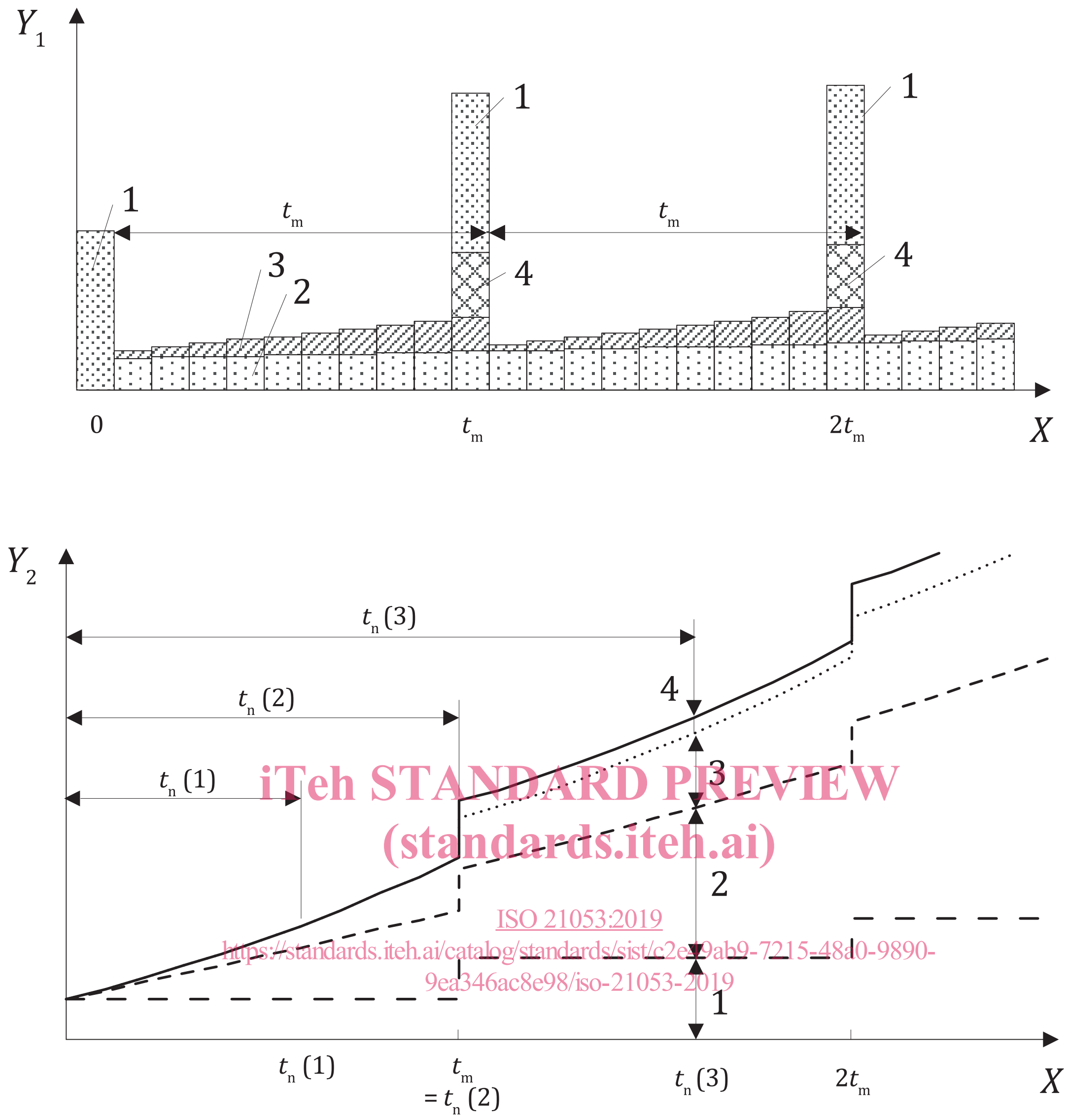
$C_{O,t}$ is the operation cost in the $t^{th}$ year;

$C_{M,t}$ is the maintenance cost in the $t^{th}$ year;

$C_E$ is the end of life cost or revenue;

$r$ is the discount rate.






**Key**

1 acquisition cost

2 operation cost

3 maintenance cost

4 end of life cost or revenue

*X* time in year

$Y_1$ cost

$Y_2$ LCC

**Figure 1 — Image of life cycle cost**

# 5 Breakdown of life cycle cost

## 5.1 Acquisition cost

The acquisition cost is calculated using Formula (5) as a total of the pipe material cost, construction cost, and designing/survey cost.

$$C_A = A_P + A_C + A_D \tag{5}$$

where

$C_A$ is the acquisition cost;

$A_P$ is the pipe material cost;

$A_C$ is the construction cost (pipe laying cost, trenching cost, backfilling cost etc.);

$A_D$ is the designing/survey cost (all the studies useful for the project).

## 5.2 Operation cost

The yearly operation cost is calculated using Formula (6) as the pumping cost such as the electric power usage cost of the pump operation. Details of the computation about the pumping cost are shown in Annex A.



$$C_{O,t} = O_{P,t} \tag{6}$$

where



$C_{O,t}$ is the operation cost in the $t^{th}$ year;

$O_{P,t}$ is the pumping cost in the $t^{th}$ year.

## 5.3 Maintenance cost

The yearly maintenance cost is calculated using Formula (7) as a total of the leakage cost, leak detection cost, repair cost, and others maintenance cost.

$$C_{M,t} = M_{L,t} + M_{D,t} + M_{R,t} + M_{O,t} \tag{7}$$

where

$C_{M,t}$ is the maintenance cost in the $t^{th}$ year;

$M_{L,t}$ is the leakage cost (cost of water losses) in the $t^{th}$ year;

$M_{D,t}$ is the leak detection cost in the $t^{th}$ year;

$M_{R,t}$ is the repair cost in the $t^{th}$ year;

$M_{O,t}$ is other maintenance cost in the $t^{th}$ year.

The yearly leakage cost is calculated using Formula (8) as a total of water loss costs due to leakage and pipeline cleaning during damage.

$$M_{L,t} = D_R \times P_L \times (L_V + V_C) \times U_P \tag{8}$$

where

$D_R$ is the damage ratio, in incident numbers per kilometre per year;

$P_L$ is the total pipeline length, in km;

$L_V$ is the water leakage volume, in cubic metres per incident;

$V_C$ is the water volume for cleaning, in cubic metres per incident;

$U_P$ is the unit price of water supply, in currency per cubic metre.

### 5.4 End of life cost or revenue

The end of life cost or revenue is calculated using Formula (9) as a total of the pipeline dismantling cost and the waste disposal cost, deducting the revenue from material recovery.

$$C_E = E_P + E_W - E_R \quad (9)$$

where

$C_E$ is the end of life cost or revenue;

$E_P$ is the pipeline dismantling cost;

$E_W$ is the waste disposal cost;

$E_R$ is the revenue from material recovery.



Material recovery is considered to be applicable only to ductile iron pipes.

## 6 Key drivers for life cycle cost reduction

The following key drivers can be highlighted:

— **Leakage:** Strong material properties and flexibility of joints contribute to prevent the leakage incident on buried ductile iron pipes. Annex C proposes examples of statistical values of incident rate per kilometre.

— **Durability:** A service life of 100 years is commonly recognized for ductile iron pipes buried in usual conditions. However, the service life can be reduced or increased considering the nature of the pipe coating and the local soil conditions.

— **Conveyance capacity:** For a given nominal diameter, ductile iron pipes are duly designed with a larger internal diameter in order to reduce the head loss on energy pumping and the operation cost such as the electric power usage cost. Annex A shows that the internal diameter is a more influent factor on the head loss than the surface roughness coefficient.

— **Recyclability:** Excavated iron pipes can be reused as a raw material to manufacture new ductile iron pipes. Benefits of lower-cost production can be expected in a case where natural resources are used, allowing the disposal cost to be reduced.

The development of new methods of laying (re-use of excavated soils for backfilling, narrow trench, etc.) can also contribute to reducing the construction cost.

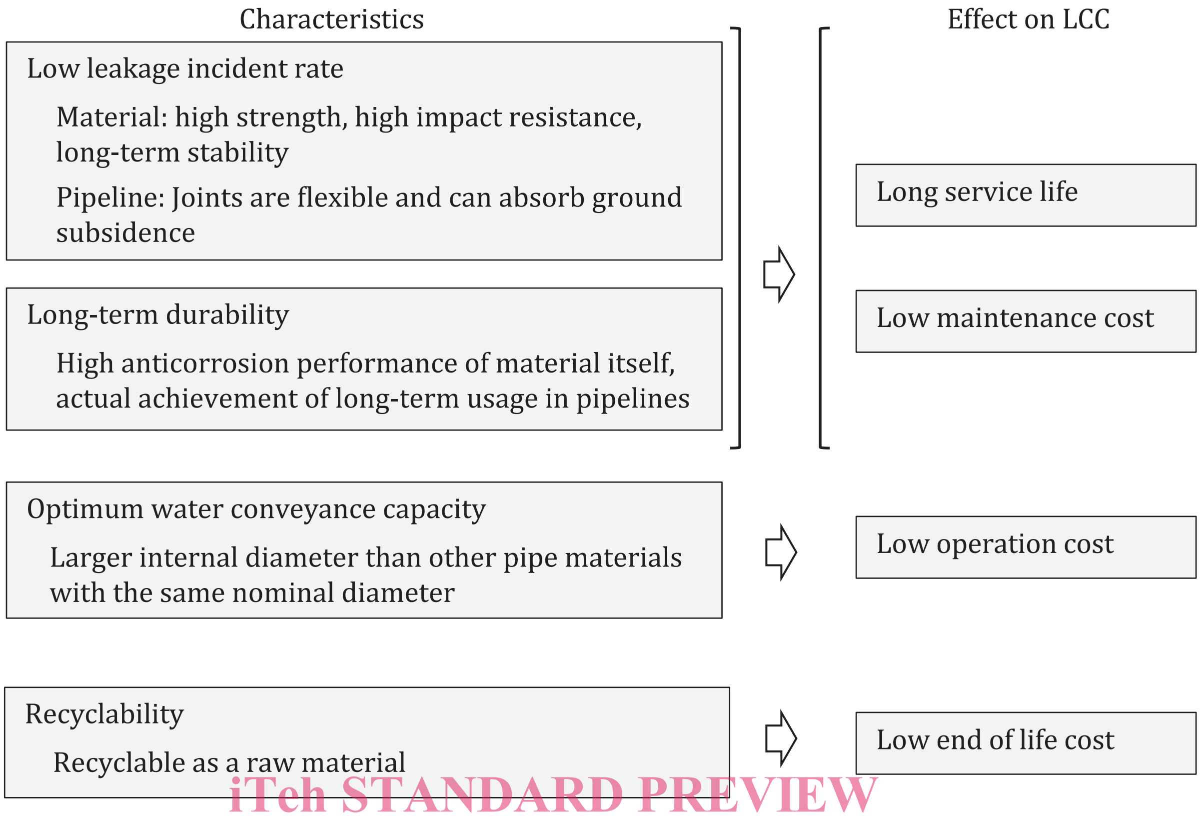





**Figure 2 — Key drivers for LCC reduction**