Mapping Life Cycle Costing: Methods, Applications, and Management Implications

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Abstract: Accurate investment evaluation requires looking well beyond the purchase price. As sustainability regulations tighten globally and stakeholder accountability pressures intensify, decision-makers need analytical tools capable of capturing the full economic picture of a product or service across its entire useful life. Life Cycle Cost (LCC) analysis provides precisely such a framework, enabling the systematic forecasting and evaluation of costs across all life cycle phases while explicitly accounting for future uncertainties. Rooted in the Life Cycle Thinking paradigm, LCC is conceptually complementary to Life Cycle Assessment (LCA), which focuses on environmental impacts, and Social Life Cycle Assessment (S-LCA), which addresses social dimension. Regulatory bodies, particularly within the European Union, have formally incorporated LCC into public procurement frameworks, enabling or, in specific sectoral contexts, mandating its adoption as an award criterion, thus accelerating its institutional diffusion. This regulatory momentum reflects a broader recognition that short-term cost comparisons are inadequate proxies for the true economic burden of long-lived assets and infrastructure investments, where operational, maintenance, and end-of-life costs frequently overshadow initial acquisition expenditures. Despite this growing recognition, LCC adoption remains characterized by significant methodological heterogeneity. Divergent cultural approaches to cost analysis, varying computational methods, inconsistent assumptions on discount rates and uncertainty treatment, and sector-specific adaptations have generated a fragmented landscape that complicates cross-sector comparability and benchmarking. This fragmentation risks undermining the reliability of LCC-based decisions when managers lack sufficient awareness of how methodological choices shape cost outcomes and, consequently, investment rankings. To address this critical gap, the present article provides a structured comparative analysis of LCC adoption across multiple industrial sectors, bridging the distance between the tool's considerable theoretical potential and its often-inconsistent practice. Such an investigation is an increasingly urgent priority: as sustainability obligations continue to reshape managerial decision-making worldwide, organizations that lack robust and methodologically sound cost assessment tools risk both competitive disadvantages and regulatory non-compliance. Understanding LCC approaches, their underlying assumptions, and their practical implications is therefore not merely an academic exercise, but a strategic imperative for practitioners operating in an era of tightening social environmental and economic accountability.

Keywords: Life cycle cost analysis, Life cycle thinking, Strategic decision-making, Sustainability decisions, Investment cost analysis

1. Introduction/Background

Over the past few decades, firms have operated in increasingly dynamic and competitive environments, characterised by rapid technological development, evolving market conditions, and growing pressure to improve the efficiency and sustainability of business activities. In this context, assessing sustainability performance has become increasingly important to support informed decision-making and the development of more sustainable business models (Goffetti *et al.*, 2022). Companies are thus required to adopt a more comprehensive approach to evaluating their activities, considering the interrelated environmental, social, and economic dimensions of sustainability (Kloepffer, 2008). In particular, sustainability assessment increasingly relies on methodologies that evaluate the impacts of products, services and processes throughout their entire life cycle (Sala *et al.*, 2013). Life Cycle Thinking provides the conceptual basis for these methodologies, including Life Cycle Assessment (LCA) for environmental impacts, Life Cycle Costing (LCC) for economic impacts, and Social Life Cycle Assessment (S-LCA) for social impacts. Their integration into Life Cycle Sustainability Assessment (LCSA) enables a more comprehensive evaluation of sustainability across all three dimensions (Bruno, Menichini and Silvestri, 2025). These life cycle-based methods have also demonstrated their value in supporting decision-making processes, both at the organisational level and in the development of public policies (Sonnemann *et al.*, 2017). From an economic sustainability perspective, firms and managers are increasingly required to look beyond initial investment and short-term returns, considering costs over the entire life cycle, including maintenance, operation, and end-of-life costs (Eldars and Sorour, 2026). This shift requires tools capable of providing decision-makers with comprehensive information to support economic evaluation throughout the life cycle (Sani *et al.*, 2026). Life Cycle Costing (LCC) addresses this need by extending the Life Cycle Thinking approach to the economic dimension and enabling the assessment of the costs associated with a product or service throughout its entire life cycle (Ashby, 2024). Although LCC is

increasingly applied and has gained sufficient relevance to be incorporated into regulatory frameworks and formal standards, substantial heterogeneity remains in the methods used, partly due to differences in geographical and industrial contexts (Bachmann *et al.*, 2024). Moreover, inconsistencies in its implementation and limitations in data quality introduce further uncertainty into LCC applications, highlighting the need for further research and methodological insights (Ilg *et al.*, 2017). Against this background, this study aims to analyse the methodologies through which LCC can be applied, providing a structured basis for understanding and correctly implementing the method, while highlighting its potential to support managers and decision-makers in the pursuit of economic sustainability.

2. Method

The first part of this study focused on presenting the development of the Life Cycle Costing (LCC) method and its widespread adoption also regarding regulatory aspects and the impact of these regulations on the further evolution of the LCC approach. A literature search was conducted in the Scopus database, selecting publications from 2016 onward. From this initial search, reviews were selected in which the articles covered LCC offering detailed explanations of the LCC method and its application, with the aim to reveal the most recent methodological approaches for implementing LCC. The authors subsequently conducted a comparative analysis of current developments in the adoption of the LCC methodology in scientific literature and managerial practice. To carry out this analysis, reviews published in the last eight years were identified in the Scopus database, where each review was conducted by authors of the same nationality and focused on articles concerning LCC. By analysing these reviews, various approaches and recurring themes in LCC were identified, depending on the geographic origin of the review authors. The results of this comparison were compiled and presented in a table. Finally, the anticipated future developments regarding the adoption of LCC were presented.

3. The Role of LCC in Governance and Management

Life Cycle Costing has been developing and spreading since the middle of the last century, primarily within military and governmental contexts. Referring to that period, Woodward (1997) describes LCC as a process employed to maximize the use of economic resources in the procurement of goods, while simultaneously accounting for all costs (purchase, maintenance, and disposal) incurred throughout the product's entire life cycle. A first distinction from traditional financial accounting thus emerges, as the latter is primarily concerned with the depreciation of an initial investment (Liapis and Kantianis, 2015). Towards the end of the century, LCC also became widespread in the civil engineering and infrastructure sectors. Although the method’s usefulness and benefits were broadly recognized, Cole and Sterner (2000) identified, as early as 2000, several operational challenges associated with its application, primarily stemming from difficulties in obtaining reliable data.

Despite these limitations, LCC has progressively gained traction, partly owing to the growing emphasis on sustainability, particularly in its environmental and economic dimensions. As this emphasis intensified, methodologies capable of quantifying environmental impacts (Life Cycle Assessment) and economic impacts (Life Cycle Costing) achieved greater acceptance and development across industries, extending beyond purely business-oriented contexts. Indeed, since the late 1990s, LCC has been adopted by the Swedish Armed Forces. Hochschorner and Finnveden (2006) monitored the first decade of its application, demonstrating the method's effectiveness despite an initial methodological fragmentation across different areas of military procurement.

A further significant step in the adoption of LCC within industrial contexts was the introduction of guidelines on economic sustainability within official regulatory frameworks. A notable example is Directive 2014/24/EU, which shifted the focus of procurement management from the initial purchase cost to the total cost incurred over the product's entire useful life cycle (European Parliament and Council Directive of 26 February 2014 on public procurement and repealing Directive 2004/18/EC, 2014). This legislation also began to address environmental costs, that is, costs potentially impacting the environment, thereby marking a transition from an approach based on the lowest initial purchase price to one based on the most economically advantageous offer, and illustrating the increasing attention devoted to LCC within EU law, policy, and practice (Czarnezki and Van Garsse, 2019).

Nonetheless, the implementation of LCC has varied considerably across institutional and geographical contexts. Whereas Directive 2014/24/EU mandates, within the EU, that companies participating in public procurement tenders evaluate the total cost of the goods or services covered by the contract through LCC calculations, the situation in the United States differs substantially. In the U.S. the use of LCC is not mandatory for companies but for federal Entities. The law 42 USC § 8254 establishes the Life Cycle Cost methods and

procedures used by the U.S. Federal Government to evaluate energy systems, water systems, and building designs (United States Code, 2024). It requires government agencies to use a consistent economic approach to ensure long-term energy efficiency and cost-effectiveness in federal construction. In addition, law 42 USC § 8259 requires federal buyers to procure energy-efficient products and to consider Life Cycle Costs, specifically mandating the selection of the lowest LCC option (United States Code, 2024). Both the laws remand to the NIST handbook (CIT) which contains the guidelines for the LCC application in those field (Kneifel, 2025).

Currently, the LCC approach is therefore widely adopted, although it continues to exhibit notable methodological heterogeneity across contexts.

4. LCC Methods: An Overview

4.1 Main Methods for Applying LCC

To clearly illustrate the LCC methodology, it is useful to outline its main application strategies, as LCC can be performed according to different criteria depending on the characteristics of the study at hand. Five main categories of methods can be identified: the Deterministic method, which discounts future costs to a reference year; the Reliability method, which addresses corrective maintenance costs and component failure behaviour; the Uncertainty and Risk Management method, which focuses on potential future contingencies; the Probabilistic/Stochastic method, which models input parameters as random variables to capture the variability of results; and the Fuzzy Set method, which represents uncertainty through membership functions when historical data are scarce. The main characteristics of each methodology are summarized in Table 1.

Table 1: Comparison of LCC Methods

Method	Aim	Strengths	Weaknesses
Deterministic method (Gulotta et al., 2022a; Zhao and Li, 2022)	Discounts projected future costs back to a reference year using a fixed discount rate to compute the Net Present Value (NPV).	Conceptually simple and computationally transparent, making it an effective decision-support tool, particularly for comparing alternative scenarios.	Because input parameters (discount rate, prices, costs) are treated as fixed, results become increasingly unreliable over long-term horizons (20–30 years), where exogenous factors such as inflation, interest-rate shifts, and energy price volatility can substantially alter actual outcomes.
Reliability method (Babashamsi et al., 2016; Farsi et al., 2023)	Estimates corrective maintenance costs using reliability-based indicators, primarily Mean Time To Failure (MTTF) and component failure rate.	High predictive accuracy, as estimates are grounded in empirical, component-specific performance data rather than generic assumptions.	Its applicability is constrained by data availability: it cannot be implemented in organizations lacking a structured historical maintenance database or sufficient cross-departmental information sharing.
Uncertainty and risk management method (Ilg et al., 2017; Scope et al., 2016)	Introduces a dedicated contingency cost item within the LCC estimate to account for unforeseen events (e.g., equipment failure, supplier price increases).	Reduces exposure to budget overruns by proactively allocating resources for unplanned expenses.	Contingency allocations are often based on subjective expert judgment or estimated probabilities of occurrence, introducing variability that limits the objectivity and reproducibility of the analysis.
Probabilistic / stochastic method (Monte Carlo simulation) (De Melo et al. 2025; Wang, Chang and El-Sheikh., 2012)	Treats key input parameters (discount rate, energy prices, maintenance costs, etc.) as random variables with assigned probability distributions and runs repeated simulations to generate a distribution of possible LCC outcomes rather than a single point estimate.	Provides a quantitative measure of result variability and confidence intervals, overcoming the rigidity of the deterministic approach and offering a more realistic picture of long-term cost uncertainty.	Requires reliable probability distributions for each input variable, which are often difficult to obtain; it is also computationally more demanding and can be harder to communicate to non-technical decision-makers than a single deterministic value.

Method	Aim	Strengths	Weaknesses
Fuzzy set method (Zhang, Yuan and Teng, 2025)	Models' uncertainty in cost parameters using fuzzy numbers and membership functions instead of crisp values or probability distributions, particularly useful when historical or statistical data are scarce.	Allows uncertainty to be represented even in data-poor contexts, capturing expert judgment and linguistic imprecision (e.g., "low," "medium," "high" cost) in a structured mathematical form.	Results depend heavily on the membership functions defined by experts, which can introduce subjectivity; the method is also less widely standardized and less intuitive for practitioners compared to probabilistic approaches.

4.2 Geographic Influence on the Area of Interest of the LCC Method

Finally, when studying the evolution of LCC methods, attention must be paid to cultural influences that may be linked to the type of approach taken to LCC. In fact, by analysing several reviews of studies conducted in different parts of the world emerges that, depending on the authors' affiliation region, different areas of analysis are prioritized. Below is a summary table of the main characteristics of certain geographic regions of the world. In particular, it is evident that in Europe, likely due to European Directives such as Directive 2014/24/EU, LCC, like LCA, is primarily applied in connection with environmental studies (Sala *et al.*, 2021). At the same time, in the U.S., the focus is on both economic and environmental aspects, but with a preference for applications to industrial processes and large-scale infrastructure, whereas in Europe, the sectors analyzed in the reviews are transportation, buildings, and agriculture. Finally, in the United Kingdom and Canada, reviews tend to focus on the construction sector, using LCC with reliability calculations.

Table 2: Comparison of LCC Application Approaches by Authors' Geographic Affiliation

Geographic area	LCC model	Aim	Sector specific application
U.S.A. **(Kaushal, Najafi and Serajiantehrani, 2020), (Luo et al., 2021)**	LCC and LCC+LCA (Life Cycle Costing)	Capital efficiency and the pursuit of maximum direct savings.	Minimizing Initial Costs in Large-Scale Infrastructure and industrial processes
Europe **(Gulotta et al., 2022b), (Mondello et al., 2023), (De Menna et al., 2018)**	E-LCC (Environmental Life Cycle Costing) and LCC+LCA (Life Cycle Costing)	Prioritize choices that are more cost-effective and more sustainable	Long-term sustainability through the inclusion of environmental impact costs (CO_2). Focus mainly on transport, building and agriculture.
United Kingdom, Canada **(Alasmari, Martinez-Vazquez and Baniotopoulos, 2022), (Jrade et al., 2023)**	LCC with reliability computation	Better Forecast Maintenance Costs	Precisely addressing the real Estate assets costs.

5. Managerial Implications

LCC has a wide range of applications in both the private and public sectors. For a private company, LCC could be useful for an internal review of the costs of its production lines and business units, and thus for optimizing production processes (Lindgreen *et al.*, 2026). Furthermore, companies are required to submit an LCC study to participate in public tenders within the European Union, according to EU 2014 Directive (European Parliament and Council Directive of 26 February 2014 on public procurement and repealing Directive 2004/18/EC, 2014). LCC, as is already the case in the U.S., can also be used by public entities themselves to determine their investment priorities within their jurisdictions (United States Code, 2024). From the perspective of management and decision-making, LCC therefore offers significant potential, to help promote Life Cycle Management, to facilitate the transition to a circular economy, and to support an effective marketing strategy. An important approach that has developed in recent decades is Life Cycle Management (LCM), a management approach adaptable to all types of companies or organizations, aimed at improving sustainability performance (Life Cycle Management - Life Cycle Initiative). This method, which can offer various practical benefits for the company in question, can draw inspiration and input from LCC, as reported by Kambanou (2020). However, the use of LCC to implement LCM must be managed rigorously to avoid excessively divergent applications of LCC methods among different users working on the same project, and to ensure that environmental objectives are not compromised by mitigating or excluding the relevant impacts (Kambanou, 2020).

LCC may also prove useful for the circular economy sector (Albuquerque *et al.*, 2019). Since the adoption of circular economy measures can be difficult for companies to adopt, LCC can provide information on current economic conditions and potential future financial implications, as well as, to some extent, on the circular recovery of resources, thereby stimulating the transition of industries or companies toward circularity (Kambanou and Sakao, 2020).

Finally, in recent years, some companies have begun to incorporate tools into their marketing strategies that are provided directly to users, allowing buyers to gain early access to estimates of potential future product maintenance costs. These tools are being implemented by a variety of companies in different sectors from automotive (IVECO COST CALCULATOR-Iveco Group)~~)~~ to Heating Ventilation and Air Conditioning (HVAC) systems (*Binnenklimaat Nederland)*, linear and rotary actuators (*Life Cycle Cost Ownership Interactive Calculator | FIRGELLI),* measuring tools *(Lifecycle Cost (LCC) | Total Cost of Ownership — Vibromera)*. LCC itself could be incorporated into marketing strategies to improve stakeholder trust in companies (Lindgreen *et al.*, 2026). Even in the public sector, tools for calculating TCO and LCC are beginning to become available, such as those from the European Union (Life-cycle costing Calculation Tools (DG ENV) | Public Buyers Community) or the International Council on Transport (Total Cost of Ownership (TCO) Calculator - International Council on Clean Transportation).

6. Future Developments

Despite its increasing use, LCC still faces technical challenges in its application. A major issue concerns uncertainty: De Melo et al. (2025) propose combining LCC with Monte Carlo simulation and real options, offering a more tractable alternative to analytical methods for mitigating uncertainty. Future developments may also involve integrating LCC with AI, although this remains at an early stage; examples include the use of Natural Language Processing (NLP) to support data extraction from technical specifications and contracts, and AI-based methods aimed at streamlining the LCC calculation process itself (Avogaro et al., 2025).

Further adoption of the method, including its direct use by end-users, also warrants closer assessment. Moreover, while LCC–LCA integration is already well established, growing attention is being directed toward also incorporating social impacts (S-LCA), with the aim of providing stakeholders and decision-makers with increasingly comprehensive and accessible tools for informed sustainability decision-making (Fauzi et al., 2019; Finkbeiner et al., 2010; Sala et al., 2013).

7. Conclusions

Over the years, LCC has evolved to take an increasing number of factors into account and to integrate with other tools, allowing it to be applied to an ever-wider range of fields. The variety of LCC calculation methods, which vary depending on the industry sector, region of the world, and the study's objectives, is matched by a variety of different entities that benefit from performing LCC calculations, as it is a method applicable to both public agencies and private companies (Goffetti et al., 2022; Sonnemann et al., 2017). From the perspective of management and decision-making, LCC offers significant potential, but experts in these fields must stay up to date and learn to properly understand and interpret the results of these studies (Bachmann et al., 2024). Furthermore, it is important that those involved in LCC strive to standardize methodologies and find ways to reduce the uncertainty of the results (Ilg et al., 2017). Future approaches to making LCC more robust include reducing uncertainty through probabilistic techniques such as Monte Carlo simulation, which has already proven effective in quantifying risk and variability in life cycle cost models for building and infrastructure projects (Wang, Chang and El-Sheikh., 2012), as well as integrating traditional LCC with artificial intelligence and machine learning systems, which can automate data collection, improve cost forecasting, and support real-time decision-making throughout the assessment process (Ghoroghi et al., 2022). It will also be important to integrate LCC with LCA and S-LCA (Bruno, Menichini and Silvestri, 2025): a combined Life Cycle Sustainability Assessment (LCSA) approach allows decision-makers to evaluate the economic, environmental, and social dimensions of a product or system simultaneously, rather than in isolation, thereby avoiding trade-offs that might otherwise go unnoticed when only one dimension is assessed. The integrated perspective makes it possible to identify solutions that are not only cost-effective but also environmentally sound and socially responsible, strengthening the overall robustness and credibility of sustainability claims. By addressing these methodological challenges and embracing greater integration with LCA and S-LCA, organizations can transform LCC from a narrow accounting exercise into a strategic tool that supports both competitive positioning and long-term sustainability goals.

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References

Alasmari, E., Martinez-Vazquez, P. and Baniotopoulos, C. (2022) "A Systematic Literature Review of the Adoption of Building Information Modelling (BIM) on Life Cycle Cost (LCC)," *Buildings 2022, Vol. 12, Page 1829*, 12(11), p. 1829. Available at: https://doi.org/10.3390/BUILDINGS12111829.

Albuquerque, T.L.M. *et al.* (2019) "Life cycle costing and externalities to analyze circular economy strategy: Comparison between aluminum packaging and tinplate," *Journal of Cleaner Production*, 234, pp. 477–486. Available at: https://doi.org/10.1016/J.JCLEPRO.2019.06.091.

Ashby, M.F. (2024) "Life Cycle Costing, LCC," *Materials and Sustainable Development*, pp. 149–181. Available at: https://doi.org/10.1016/B978-0-323-98361-7.00007-5.

Avogaro, D. *et al.* (2025) "Mapping Cost Intersection Through LCC, BIM, and AI: A Systematic Literature Review for Future Opportunities." Available at: https://doi.org/10.3390/buildings15183345.

Babashamsi, P. *et al.* (2016) "Evaluation of pavement life cycle cost analysis: Review and analysis," *International Journal of Pavement Research and Technology*, 9(4), pp. 241–254. Available at: https://doi.org/10.1016/J.IJPRT.2016.08.004.

Bachmann, T.M. *et al.* (2024) "Life cycle costing as part of a life cycle sustainability assessment of products: methodology and case studies," *The International Journal of Life Cycle Assessment 2024 29:10*, 29(10), pp. 1863–1879. Available at: https://doi.org/10.1007/S11367-024-02347-1.

Binnenklimaat Nederland. Available at: https://www.vlalcc.nl/ (Accessed: June 26, 2026)

Bruno, A., Menichini, T. and Silvestri, L. (2025) "Life Cycle Sustainability Assessment (LCSA): A comprehensive overview of existing integrated approaches to LCA, S-LCA, and LCC," *European Journal of Sustainable Development*, 14(3), pp. 13–13. Available at: https://doi.org/10.14207/EJSD.2025.V14N3P13.

Cole, R.J. and Sterner, E. (2000) "Reconciling theory and practice of life-cycle costing," *Building Research & Information*, 28(5–6), pp. 368–375. Available at: https://doi.org/10.1080/096132100418519.

Czarnezki, J.J. and Van Garsse, S. (2019) "What is Life-Cycle Costing?," *Cost and EU public procurement law: life-cycle costing for sustainability* [Preprint]. Routledge Press. Available at: https://papers.ssrn.com/abstract=3789958 (Accessed: June 24, 2026).

De Melo, G.A. *et al.* (2025) "Optimizing forest sector performance based on life cycle cost analysis and real options," *Science of The Total Environment*, 988, p. 179675. Available at: https://doi.org/10.1016/J.SCITOTENV.2025.179675.

De Menna, F. *et al.* (2018) "Life cycle costing of food waste: A review of methodological approaches," *Waste Management*, 73, pp. 1–13. Available at: https://doi.org/10.1016/j.wasman.2017.12.032.

Eldars, E.A. and Sorour, A.A. (2026) "Life cycle cost reliability assessment for strategic real estate decision-making," *Expert Systems with Applications*, 298, p. 129329. Available at: https://doi.org/10.1016/J.ESWA.2025.129329.

European Parliament and Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC (2014) "DIRECTIVE 2014/24/EU," *Public procurement of European Parliament and Council*. Available at: https://eur-lex.europa.eu/eli/dir/2014/24/oj/eng (Accessed: June 24, 2026).

Farsi, M. *et al.* (2023) "A Robust Design for Lifecycle Cost with Reliability Analysis Integration," *Procedia CIRP*, 119, pp. 248–253. Available at: https://doi.org/10.1016/J.PROCIR.2023.05.004.

Fauzi, R.T. *et al.* (2019) "Exploring the Current Challenges and Opportunities of Life Cycle Sustainability Assessment," *Sustainability 2019, Vol. 11, Page 636*, 11(3), p. 636. Available at: https://doi.org/10.3390/SU11030636.

Finkbeiner, M. *et al.* (2010) "Towards Life Cycle Sustainability Assessment," *Sustainability 2010, Vol. 2, Pages 3309-3322*, 2(10), pp. 3309–3322. Available at: https://doi.org/10.3390/SU2103309.

Ghoroghi, A. *et al.* (2022) "Advances in application of machine learning to life cycle assessment: a literature review," *The International Journal of Life Cycle Assessment 2022 27:3*, 27(3), pp. 433–456. Available at: https://doi.org/10.1007/S11367-022-02030-3.

Goffetti, G. *et al.* (2022) "Towards sustainable business models with a novel life cycle assessment method," *Business Strategy and the Environment*, 31(5), pp. 2019–2035. Available at: https://doi.org/10.1002/BSE.3005.

Gulotta, T.M. *et al.* (2022a) "Life Cycle Assessment and Life Cycle Costing of unitized regenerative fuel cell: A systematic review," *Environmental Impact Assessment Review*, 92, p. 106698. Available at: https://doi.org/10.1016/J.EIAR.2021.106698.

Gulotta, T.M. *et al.* (2022b) "Life Cycle Assessment and Life Cycle Costing of unitized regenerative fuel cell: A systematic review," *Environmental Impact Assessment Review*, 92, p. 106698. Available at: https://doi.org/10.1016/J.EIAR.2021.106698.

Hochschorner, E. and Finnveden, G. (2006) "Life cycle approach in the procurement process: The case of defence materiel," *International Journal of Life Cycle Assessment*, 11(3), pp. 200–208. Available at: https://doi.org/10.1065/lca2005.10.230.

Ilg, P. *et al.* (2017) "Uncertainty in life cycle costing for long-range infrastructure. Part I: leveling the playing field to address uncertainties," *International Journal of Life Cycle Assessment*. Springer Verlag, pp. 277–292. Available at: https://doi.org/10.1007/s11367-016-1154-1.

IVECO COST CALCULATOR-Iveco Group (no date). Available at: https://tco.iveco.com/my2024/calculator.html?country=uk&lang=en (Accessed: June 25, 2026).

Jrade, A. *et al.* (2023) "Potential Integration of Bridge Information Modeling and Life Cycle Assessment/Life Cycle Costing Tools for Infrastructure Projects within Construction 4.0: A Review," *Sustainability (Switzerland)*, 15(20), p. 15049. Available at: https://doi.org/10.3390/SU152015049/S1.

Kambanou, M.L. (2020) "Life Cycle Costing: Understanding How It Is Practised and Its Relationship to Life Cycle Management—A Case Study," *Sustainability 2020, Vol. 12, Page 3252*, 12(8), p. 3252. Available at: https://doi.org/10.3390/SU12083252.

Kambanou, M.L. and Sakao, T. (2020) "Using life cycle costing (LCC) to select circular measures: A discussion and practical approach," *Resources, Conservation and Recycling*, 155, p. 104650. Available at: https://doi.org/10.1016/J.RESCONREC.2019.104650.

Kaushal, V., Najafi, M. and Serajiantehrani, R. (2020) "Environmental Impacts of Conventional Open-Cut Pipeline Installation and Trenchless Technology Methods: State-of-the-Art Review," *Journal of Pipeline Systems Engineering and Practice*, 11(2). Available at: https://doi.org/10.1061/(ASCE)PS.1949-1204.0000459.

Kneifel, J. (2025) *Life Cycle Costing Manual for the Federal Energy Management Program*. Available at: https://doi.org/10.6028/NIST.HB.135e2025

Kloepffer, W. (2008) "Life cycle sustainability assessment of products", *Int J Life Cycle Assess* 13, 89–95. Available at: https://doi.org/10.1065/lca2008.02.376

Liapis, K.J. and Kantianis, D.D. (2015) "Depreciation Methods and Life-cycle Costing (LCC) Methodology," *Procedia Economics and Finance*, 19, pp. 314–324. Available at: https://doi.org/10.1016/S2212-5671(15)00032-5.

Life Cycle Cost Ownership Interactive Calculator | FIRGELLI. Available at: https://www.firgelliauto.com/blogs/calculators/life-cycle-cost-ownership-calculator?srsltid=AfmBOort7HQf2pIPmToKOxmp91umU_DuwjIrADzqJxzgPsS52Xv509aX (Accessed: June 26, 2026).

Life Cycle Management - Life Cycle Initiative (no date). Available at: https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/life-cycle-management/ (Accessed: June 25, 2026).

Lifecycle Cost (LCC) | Total Cost of Ownership — Vibromera (no date). Available at: https://vibromera.eu/calculators/lifecycle-cost-calculator/?acq=5000&inst=1000&energy=500&maint=300&life=15&rate=5&cur=EUR (Accessed: June 26, 2026).

Life-cycle costing Calculation Tools (DG ENV) | Public Buyers Community (no date). Available at: https://public-buyers-community.ec.europa.eu/resources/life-cycle-costing-calculation-tools-dg-env (Accessed: June 30, 2026).

Lindgreen, Adam. *et al.* (2026) "The Sage Handbook of Industrial Marketing." Available at: https://books.google.com/books/about/The_Sage_Handbook_of_Industrial_Marketin.html?hl=it&id=a8quEQAAQBAJ

Luo, J. *et al.* (2021) "Review of Advances in Engineering Nanomaterial Adsorbents for Metal Removal and Recovery from Water: Synthesis and Microstructure Impacts," *ACS ES and T Engineering*, 1(4), pp. 623–661. Available at: https://doi.org/10.1021/acsestengg.0c00174.

Mondello, G. *et al.* (2023) "Life Cycle Assessment and Life Cycle Costing for assessing maritime transport: a comprehensive literature review," *Maritime Policy and Management*, 50(2), pp. 198–218. Available at: https://doi.org/10.1080/03088839.2021.1972486.

Sala, S. *et al.* (2021) "The evolution of life cycle assessment in European policies over three decades," *The International Journal of Life Cycle Assessment 2021 26:12*, 26(12), pp. 2295–2314. Available at: https://doi.org/10.1007/S11367-021-01893-2.

Sala, Serenella *et al.* (2013) "Life cycle sustainability assessment in the context of sustainability science progress (part 2)," *Int J Life Cycle Assess*, 18, pp. 1686–1697. Available at: https://doi.org/10.1007/s11367-012-0509-5.

Sani, A.A. *et al.* (2026) "A critical and bibliometric review of life cycle cost analysis integration into decision support systems for pipeline asset integrity management," *Journal of Pipeline Science and Engineering*, 6(1), p. 100307. Available at: https://doi.org/10.1016/J.JPSE.2025.100307.

Sonnemann, G. *et al.* (2017) "Life cycle thinking and the use of LCA in policies around the world," *Life Cycle Assessment: Theory and Practice*, pp. 429–463. Available at: https://doi.org/10.1007/978-3-319-56475-3_18.

Scope, C. *et al.* (2016) "Uncertainty in life cycle costing for long-range infrastructure. Part II: guidance and suitability of applied methods to address uncertainty," *International Journal of Life Cycle Assessment*. Springer Verlag, pp. 1170–1184. Available at: https://doi.org/10.1007/s11367-016-1086-9.

Total Cost of Ownership (TCO) Calculator - International Council on Clean Transportation. Available at: https://theicct.org/tco-calculator/#/?vehicle_class=89953&region=89964&charger_type=89950&charger_cost=40000&number_of_chargers=1&charger_maintenance=1000&infrastructure_useful_life=15&vehicle_purchase_price=65000&fuel_economy=15&maintenance_cost=0.14&bev_purchase_price=80000&battery_capacity=100&electric_efficiency=1&battery_replacement_cost=20000&battery_warranty_period=8&bev_maintenance_cost=0.08&federal_excise_tax_diesel=0&federal_excise_tax_bev=0&sales_tax=7.5&diesel_price=4.5&diesel_price_escalation=2.5&charging_type=private&private_electricity_escalation=1.5&public_electricity_escalation=2&public_electricity_monthly_fee=0&private_electricity_rate=0.13&public_charging_rate=0.45&statelocal_incentives_bev=0&infrastructure_tax_credit=30&discount_rate=3.5&payment_method=89954&residual_value_diesel=25&residual_value_bev=20&driver_labor_cost=30&charging_time_per_cycle=2&insurance_premium_difference_bev=25&gvwr_diesel=80000&gvwr_bev=82000&curb_weight_diesel_tr

actor=15000&curb_weight_bev_tractor=20000&empty_trailer_weight=12500&actual_average_payload=12500&analysis_period=5&annual_mileage=100000 (Accessed: June 30, 2026).

United States Code, 2024 Edition, Title 42 (2024) *42 U.S.C. 8259 - United States Code, 2024 Edition, Title 42*, *govinfo.gov*. U.S. Government Publishing Office. Available at: https://www.govinfo.gov/app/details/USCODE-2024-title42/USCODE-2024-title42-chap91-subchapIII-partB-sec8259 (Accessed: June 26, 2026).

United States Code, 2024 Edition, Title 42 (2024) *42 U.S.C. 8254 - United States Code, 2024 Edition, Title 42*, *govinfo.gov*. U.S. Government Publishing Office. Available at: https://www.govinfo.gov/app/details/USCODE-2024-title42/USCODE-2024-title42-chap91-subchapIII-partB-sec8254 (Accessed: June 26, 2026).

Wang, N., Chang, Y.C. and El-Sheikh, A.A. (2012) "Monte Carlo simulation approach to life cycle cost management," *Structure and Infrastructure Engineering*, 8(8), pp. 739–746. Available at: https://doi.org/10.1080/15732479.2010.481304.

Woodward, D.G. (1997) "Life cycle costing—Theory, information acquisition and application," *International Journal of Project Management*, 15(6), pp. 335–344. Available at: https://doi.org/10.1016/S0263-7863(96)00089-0.

Zhang, W., Yuan, T. and Teng, Y. (2025) "Life cycle cost assessment of PEM water electrolysis systems: a system dynamics–intuitionistic fuzzy bayesian network approach," *Energy Conversion and Management: X*, 28, p. 101237. Available at: https://doi.org/10.1016/J.ECMX.2025.101237.

Zhao, J. and Li, S. (2022) "Life cycle cost assessment and multi-criteria decision analysis of environment-friendly building insulation materials - A review," *Energy and Buildings*, 254, p. 111582. Available at: https://doi.org/10.1016/J.ENBUILD.2021.111582.