Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

REVIEW ON THE TOOLS USED IN THE LIFE CYCLE COST ANALYSIS

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Abstract

Life cycle cost analysis (LCCA) is part of the life cycle evaluation methods, highlighting the overall economic cost of a specific product, service or system. The life cycle costs are the sum of the direct, indirect, recurring, nonrecurring and other related costs incurred or estimated to be incurred during the useful life span. This method can be a powerful technique enabling to make the most cost-effective decisions at different life cycle stages. An integrated life cycle evaluation study could combine more methods: Life cycle assessment (ISO 14040:2006), Life cycle cost analysis and social Life cycle assessment. So far, several specific instruments had been developed, IT tools and methods for LCCA method, alone or combined with LCA or other methods. The objective of this study was to present a review of the software instruments used in the Life cycle cost analysis. The LCCA method can be used in particular to model different scenarios. It allows the simulation of several analysis alternatives by resizing the volume of costs from key points.

Key words: *LCCA, life span, cost-effective decisions*

INTRODUCTION

In this paper, we need to start by presenting what an LCCA analysis is and what it is used for. Also, we find it important to present the fields in which the use of this method began and the areas in which it has expanded until now. LCCA is an analysis technique used to assess the overall long-term economic efficiency between functionally equivalent competing products or processes. So, LCCA is a decision support tool. Being based on well-founded economic principles, the method identifies the strategy that will bring you the best value and which at the same time offers the expected performance at the lowest cost, over the entire analysis period. Regarding the existence of softwares for LCCA calculation, they are found depending on the field in which they are used. Thus, among the many existing dedicated platforms for the industrial field, we only mention here some of these: • RealCost of FHWA • StreetPave and WinPAS from ACPA • CANPave from CAC • Asphalt Pavement Alliance (APA) LCCA Original and LCCA Express etc. More elements regarding the availability and diversity of support platforms for the LCCA method can be found in the Results section. Meanwhile, the LCCA analysis can be performed at different levels of complexity. Its scope can vary from a study on a narrow area of the target process to a detailed analysis with thoroughly researched input data, with additional measures of economic evaluation and assessment of the degree of uncertainty, based on extensive documentation. It is recommended that the scope of the effort be adapted to the needs of the project. Thus, LCCA will provide a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on initial costs or short-term operating costs. LCCA can be applied to capital investment decisions, where relatively higher initial costs are traded for lower future cost obligations. Because LCCA analysis is a method of evaluating the total cost of ownership of the facility, it considers all the costs of acquiring, owning and disposing of a product or service, becoming particularly useful when design alternatives that meet the same performance requirements, but differ in initial costs and operating costs, must be compared to select the one that maximizes net savings. The lowest life cycle cost (LCC) is the simplest and easiest to interpret economic evaluation measure. Other commonly used measures are net benefit, savings-to-investment ratio (or benefit-to-cost savings ratio), internal rate of return, and payback period. They are consistent with the lowest life cycle cost of assessment if they use the same parameters and the same length of study period. Life cycle cost (LCC) analysis can be applied to determine the cost of ownership of a technology (as long as this technology remains in the analyzed location). Meanwhile, in many cases the necessary information is not available or it is unknown and thus it is need to compare or making estimations. On the other hand, it is necessary to underline the cost of not doing the proper process. Not very well managed technologies consume wasted resources, especially economic resources that can well be used for other requirements [28]. An LCCA can be performed in either constant dollars or current dollars, both methods of calculation producing identical present-value life-cycle costs. Still, a constant-dollar analysis does not include the general rate of inflation, while a current-dollar analysis does include it [17]. “Analyzed two methods in a paper: the techno-economic analysis (TEA) and the life cycle cost analysis (LCCA) stated that there are the most widely used approaches for modelling and calculating processes’ economic impacts. A simulation-based TEA is a cost-benefit analysis that simultaneously considers technical and economic factors” [2]. On the other hand, there are authors stating that, “with respect to technological innovation, two diffused methods are the techno-economic assessment (TEA) and the life-cycle costing analysis (LCCA). However, despite their diffusion and approval, these instruments still lack clear guidelines and a complete documentation of their distinctive elements. Furthermore, no discussion exists about their complementarity and integrability, despite the fact that these methods are frequently concurrently used in the analyses” [14]. There are other texts that stated of a common European approach to this method, “It therefore appears appropriate to continue on that path, leaving it to sector-specific legislation to set mandatory objectives and targets in function of the particular policies and conditions prevailing in the relevant sector and to promote the development and use of European approaches to life-cycle costing as a further underpinning for the use of public procurement in support of sustainable growth” [9]. Regarding the methodology approached, we must mention the official European regulations. This refers to the fact that when we apply the cost-benefit method, as part of the LCCA analysis, we should consider the stage of identifying alternative scenarios "All relevant alternatives for the reference scenario are considered. Scenarios that are not feasible for technical, financial, national regulatory reasons or due to time constraints can be excluded at an early stage of the cost-benefit analysis” [20].

MATERIALS AND METHODS

Life Cycle Cost Analysis (LCCA) is an indispensable technique that uses well-established principles of economic analysis to evaluate the long-term performance of several competing investment options. The LCCA value is obtained by summing up the discounted monetary values of all the benefits and costs that are expected to be incurred for each option. The investment option that brings maximum profits to society is considered the optimal solution. The purpose of an LCCA is to estimate the overall costs of design alternatives and select the design that ensures the system under study will provide the lowest total cost of ownership consistent with its quality and function. LCCA should be performed early in the design process while there is still a chance to refine the design to ensure a reduction in life cycle costs (LCC). The first and most difficult task of an LCCA or any economic evaluation method is to determine the economic effects of alternative projects and to quantify these effects and express them in amounts of money. The steps used in the LCCA methodology can be different as number and structure, from one analyzed system to another, but they are mandatory aspects to follow: establish alternative design strategies, determine activity timing, estimate agency costs, estimate user costs and finally, determine life-cycle cost. Also, the analytical framework of LCCA represents a support system for choosing the input parameters and interpreting the results, which often have a rather high degree of uncertainty, such as the discount rate, used to transform the costs from the different periods, in a common time frame. In order to use the LCCA method in a relevant manner, an understanding of the process is needed both at the theoretical and economic level. The LCCA method compares the alternatives for the life-cycle cost calculation, based on some indicators, for making the best decisions. This requires that the alternatives considered be compared using a common measure of economic value, thus determining the strategies that can be applied. There are several indicators used in defining the alternatives.

For the calculation and interpretation of these indicators, as analysis tools, it has been observed that most modern calculation programs include standard functions for calculating the present value and the annual value (i.e. NPV and EUAC). At the same time, because the different components of the LCCA indicate different things about the alternatives under consideration, these components are usually viewed separately to aid interpretation and evaluation. When two alternatives have very similar net present values over the analysis period, it is advisable to choose the less risky alternative (i.e. the one with the higher proportion of net present value attributable to initial costs), thus LCCA becomes a strategic decision support tool. Following the evaluation of the production process, the economic indicators should be calculated. They will be summing up the monetary values of all revenues and costs evaluated at the time of their production, throughout the entire reference period. Therefore, these amounts will have to be converted into a common time dimension. For this purpose, several alternative methods will be used, among which we will mention the most common.

These are:

Net Present Value:

$$(NPV = \sum_{t=0}^{T} \frac{R_t - C_t}{(1+d)^t}) \qquad ....(1)$$

Cost-Benefit Ratio:

$$(B/C: \frac{PVR}{PVC} = \sum_{t=0}^{T} \frac{\frac{R_t}{(1+d)^t}}{\frac{C_t}{(1+d)^t}}) \qquad ....(2)$$

Equivalent Uniform Annual Costs (EUAC) and Internal Rate of Returns (IRR).

The choice of one or another method depends on the level and context in which the analysis is carried out and also on the degree of uncertainty of some parameters. For example, if it is found a high degree of uncertainty of the discount rate within the analyzed area, then it is preferable to use the IRR indicator. The formula of Internal Rate of Return is:

$$IRR = \sum_{t=0}^{T} \frac{R_t - C_t}{(1+IRR)^t} = 0 \qquad ....(3)$$

Another alternative is when the analysis period of the process is not known precisely or it is estimated that the period is indefinite. In this case, the EUAC indicator will be used, because it works with the assumption that the process will have an indefinite duration. The formula is the following:

$$EUAC = NPV * \left[\frac{d(1+d)^t}{(1+d)^t - 1}\right] \qquad ....(4)$$

where:

NPV = Net present Value of future costs and benefits,
IRR = Internal Rate of Returns,
B/C = Benefit/Cost,
PVB = Present value of future benefits,
PVC = Present value of future costs,
d = discount rate,
t = time (year),
T = life time of the project/process (or analysis period, years),
R_t = Revenues to be gain at time t,
C_t = costs to be incurred at the time t.

Having these considerations, the choice of an economic indicator or another should answer several questions, including the level of

PRINT ISSN 2284-7995, E-ISSN 2285-3952

benefits and the decision-making analysis involved, the requirements of the initial investments and the future costs etc. [23]. There are numerous costs associated with purchasing, operating, maintaining and disposing of a product or process system, with costs typically falling into the following categories: • initial costs (acquisition costs, construction costs etc.), • fuel costs, • operating, maintenance and repair costs, • replacement costs, • residual values—resale or disposal costs, • financing expenses—interest payments on loans, • non-monetary benefits or costs etc. [12]. Only those costs within each category that are relevant to the decision and significant in amount are necessary to make a valid investment decision. Costs are relevant when they are different for one alternative compared to another and are considered significant when they are large enough to make a credible difference in the LCC of a project alternative. At the same time, the identification and evaluation of those costs that appear during the entire process, represents an important stage in the LCCA analysis. In the figure below (Fig. 1), we have represented a schematization of this typology of costs, namely production costs, processing costs, packaging and labelling costs, retailing costs and transport costs.

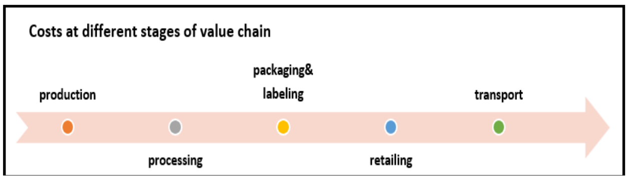

Fig. 1. Costs at different stages of value chain
Source: Own conception.

At this moment it is necessary to mention the fact that in the LCC analysis, an important stage is establishing the size of the analyzed system, called the system boundaries. This will determine the stage in the value chain up to which the costs will be considered. These limits can be set at the level of the production stage or at the level of the packaging and labelling stage etc., which will cause some LCCA analyses to include some longer stages and processes, and others, shorter. That is why it is very important to establish from the beginning the size of the system to which the analysis refers. It should also be mentioned here that the identification of hot points will be done on this system boundaries. Boundaries could be in temporal, spatial, functional and methodological dimensions. In other words, this is the identification of hot points where cost reduction can be considered for the optimization of the production options. These steps apply in any LCCA analysis. In the agricultural system, this analysis has its peculiarities, in the sense that the points are identified according to the stages of the production cycle and the type of production. In Table 1 it is listed an example of life cycle stages and system boundaries, for an apple orchard. We thus identified three big stages and substages): (A) Agricultural production stage costs, (B) Post-harvest stage costs and (C) Transport costs.

Table 1. LCCA steps on Apple supply chain with the Life cycle stages and system boundaries

(A) Agricultural production stage costs (APC)
(I) Apple farm establishment (AFE)
(1) Capital costs at apple farm establishment (AFE investment): land preparation, planting, anti-hail support system and net
(2) Operational costs at apple farm establishment (AFE operational): clearing (deforestation) – process, land preparation, planting, anti-hail support system and net, irigation system, drilling, water reservoir, irrigation
AFE TOTAL cost = AFE investment costs + AFE operational costs
(II) I-III years Orchard maintenance (Field operation cost without harvesting) (OM.I-III)
(1) Capital costs in the first 3 years of orchard maintanance (OM. I-III investment): prunning, weeds management, fertilization, pest and diseases
(2) Operational costs in the first 3 years of orchard maintanance (OM. I-III operational): prunning, weeds management, fertilization, pest and diseases, irrigation
OM. I-III TOTAL costs =OM.I-III investment costs + OM.I-III operational costs
(III) IV-XX years Orchard maintenance (Field operation with harvesting) (OM.IV-XX)
(1) Capital costs (OM.IV-XX investment): prunning, weeds management, fertilization, pest and diseases, irrigation
(2) Operational costs (OM.IV-XX operational): prunning, weeds management, fertilization, pest and diseases, irrigation, harvesting
OM.IV-XX TOTAL costs = OM.IV-XX investment costs + OM.VI-XX operational cost
(A) TOTAL costs APC = AFE TOTAL costs + OM. I -III TOTAL costs + OM.IV-XX TOTAL costs
(B) Post-harvest stage costs (PHC)
(1) Capital costs at post-harvest level (PHC investment): storage, packaging
(2) Operational costs at post-harvest level (PHC operational): sorting, storage, packaging
(B) TOTAL cost PHC = PHC investment costs + PHC operational costs
(C) Transport costs (TC)
(2) Operational costs at transport cost (TC operational): transport from field to warehouse, transport from warehouse to retail
(C) TOTAL costsTC operational = TC operational costs

SYSTEM BOUNDARIES OF THE LCCA METHOD

(A) Agricultural production stage (APC) (I + II + III)	**APC (I+II+III)**	
(I) Apple farm establishment (AFE)	APC I	Investment costs + Operational costs = TOTAL costs
(II) I-III years Orchard maintenance (without harvesting) (OM.I-III)	APC II	
(III) IV-XX years Orchard maintenance (with harvesting) (OM.IV-XX)	APC III	
(B) Post-harvest level (PHC)	**PHC**	
(C) Transport cost (TC)	**TC**	
LCC =	**APC+PHC+TC**	**TOTAL cost/(no. of years*yearly average production)**

Source: own representation.

Thus, considering Table 1, we can calculate in which of the stages (A), (B) or (C), as well as in the related sub-stages, it can be identified operations or materials for which costs can be reduced.

RESULTS AND DISCUSSIONS

The results that can be obtained and the benefits that we can record, interpret and use following the application of the LCCA method, will be different, depending on the level of detail of the stages and sub-stages, as well as the system boundaries we are referring to.

Also, the rules of economic calculation must be respected, namely, when we refer to an analysis over a long period of time, we must consider the reference period. In this sense, the costs will have to be adjusted to constant values for the entire time period of use of the process or system, that is to say, they should be evaluated as present value. In specialized literature, it is mentioned that certain additional measures of alternative economic evaluation can also be taken into account, such as: net savings (NS - operational savings less difference in capital investment costs), savings-to-investment ratio (SIR - ratio of operational savings to difference in capital investment costs), adjusted internal rate of return (AIRR - annual yield from an alternative over the study period, taking into account reinvestment of interim returns at the discount rate), and simple payback (SPB - time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, without taking into account the time value of money) or discounted payback (DPB - time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, taking into account the time value of money).

Therefore, when evaluating the criteria for possible alternatives, the following relationships will be considered: lowest LCC (for determining cost-effectiveness); NS > 0 (for determining cost-effectiveness); SIR > 1 (for ranking projects); AIRR > discount rate (for ranking projects); SPB and DPB < than study period (for screening projects).

At the same time, when interpreting the results (evaluation of alternatives), the degree of uncertainty will also be considered (Uncertainty Assessment).

In the case of long-term projects, performing an LCCA involves a growing likelihood to choose a project that saves money (on the long term).

This long term will involve a certain uncertainty on the costs level and other inputs values which will suppose some differences in final outcomes against the initial ones.

There are techniques for estimating the cost of choosing the "wrong" project alternative. These are sensitivity analysis or breakeven analysis, which are easily performed without requiring additional resources and usually it is part of the LCCA method.

They produce a single-point estimate of how uncertain input data affect the analysis outcome. Sensitivity analysis is useful for: identifying which of uncertain input values has the greatest impact and affects the range on a specific measure of economic evaluation. This could be done for identify critical parameters by testing different alternatives to answer "what if?" question, by changing the value of each input and holding all others constant, and then recalculate the economic measure to be tested [12].

The fields in which the LCCA method is applied are among the most diverse. It is used most of the time together with the LCA (Life cycle assessment) method. In agriculture, these methods appeared relatively recently, being more often used before in industry or in the construction sector, as seen in the methodology section.

As the objective of this article was the inventory of the software that can be used in LCCA analysis, in the following table we have summarized the LCCA applications that currently exist on the market and the fields in which they are used (Table 2).

Table 2. Platforms that offers support for the LCCA method

	Short description	Link	Usage field	Observations
1	The software uses reliability information to calculate a product's cost of ownership. The ability to accurately predict life cycle costs is a key concern in consumer as well as commercial sectors	https://3hti.com/products-2/windchill-quality-solutions/windchill-life-cycle-cost/ [29]	PTC Windchill LCC (formerly Relex Life Cycle Cost): offers industry-standard cost breakdown analysis tools; provides a powerful, flexible LCC tool to meet the cost analysis; compare the cost impact of several alternatives side-by-side, calculate sensitivity and net present value (NPV), and forecast costs throughout the **design**, **production**, repair and **disposal** phases	Account for many different types of costs over the lifetime of a product. Calculate costs, including total lifetime cost, overall system costs, and line-item costs. Perform design and development cost analyses to calculate system planning, concept design, and preliminary system design costs.
2	openLCA offers the largest collection of data sets and database worldwide for LCA software.	https://www.openlca.org/ [22]	openLCA is versatile and able to meet needs of different user groups, be it e.g. **industry**, **consultancy**, **education**, and **research**. It plays in the same league as commercial LCA software, such as SimaPro, GaBi, or Umberto	Very detailed insights into calculation and analysis results; Life Cycle Costing and social assessment smoothly integrated in the life cycle model. User-friendly; user interface in a variety of languages; advanced and efficient repository and collaboration feature.
3	The CBS may be directly linked to cost predictions produced by the RCMCost or AvSim modules.	https://www.isograph.com/software/availability-workbench/life-cycle-cost/life-cycle-cost-analysis/ [16]	The costs may be integrated with predicted costs in the LCC cost breakdown structure to provide a time-dependent analysis of a system's whole life cycle cost process.	The Life Cycle Cost (LCC) module of Availability Workbench allows users to build a **hierarchical cost breakdown structure** (CBS) through an unlimited number of indenture levels.
4	RealCost - the products are in Microsoft Excel spreadsheets with additional Visual Basic for Applications code to provide the graphic user interface.	https://www.fhwa.dot.gov/infrastructure/asstmgmt/lccasoft.cfm [27]	This software provides a tool to perform LCCA for **pavement** selection in accordance with FHWA best practice methods.	The version currently in production is Realcost 2.5.The best practices are outlined in the FHWA's "Life-Cycle Cost Analysis Primer," (.pdf). The software methodology is fully documented in the FHWA's "Life-Cycle Cost Analysis Technical Bulletin," (.pdf)
5	D-LCC (Decision by Life Cycle Cost) makes the LCC analysis easy & comprehensive. It is a key tool for managers, decision-makers, engineers and other staff involved in system acquisition, proposal writing, production and through-life support	https://aldservice.com/D-LCC.html [1]	Life Cycle Cost (LCC) analysis and Total Cost of Ownership evaluation are the basis for decision making for the wide range of **industries** and **equipment**: from IT systems to submarines. LCC analyzes the total ownership costs of various design alternatives and system's components over the projected life cycle of a system.	D-LCC combines the Cost Breakdown Structure (CBS) with Product Breakdown Structure (PBS) and applies the bottom-up calculation incorporating the time-scale (life cycle phases).D-LCC is data compatible with other ALD packages for Reliability, Maintainability and Logistics Analysis such as RAM Commander.
6	Opus Suite is used by industry leaders worldwide, in all phases of the system life cycle, to simulate, evaluate and understand how key decisions regarding the design of the technical system, its maintenance & support solution will impact costs & performance.	https://www.systecongroup.com/us/knowledge-center/life-cycle-cost-analysis [26]	Opus Suite can be used in LCC Analyses to for example: model and simulate the cost impact of **decisions**, **compare alternative solutions**, identify cost drivers, identify the most cost-effective changes and improvements, evaluate **financial risks** and sensitivity to data uncertainty, budgeting and **forecasting**.	The flexible scenario modelling in Opus Suite means that cost structure, complexity, formulas, KPI:s etc may be fully tailored to the scope and objectives of the analysis.
7	The program data is based upon real life data collected at facilities around the world for real world results as opposed to theoretical calculations	https://www.camfil.com/en-us/support-and-services/design-and-engineering/life-cycle-costing-software [5]	Camfil introduced filter life-cycle costing software in the early nineties. The latest version, Camfil LCC Green, considers filter efficiency, **filter life**, filter change **labor**, filter cost, **disposal** costs and allows inputs for all of these factors, plus the largest filter expense, energy usage.	The software has a criterion with guidance to input the specific air quality parameters for a geographic area, based upon data from authorities, such as the United States Environmental Protection Agency (EPA).
8	LCC analysis software is a Decision Support tool for Design of asset / fleet, maintenance concept, ROI analysis of **IIoT systems**, **tender** bids, **planning** overhauls	https://www.bqr.com/products/apmoptimizer/lcc-life-cycle-cost/ [3]	The main features are: Flexible asset behaviour model, Part libraries, Import tree from Excel or BQR CARE, Fast analytic calculations, Detailed help and wizard	LCC is an important asset KPI that combines financial, technical and logistic aspects of the asset. BQR's LCC module allows to easily define all aspects of the asset operation and maintenance, allowing to calculate the expected LCC of complex assets, accounting for **maintenance**, inspections, spare parts,

				transportation, failure and down time cost. This is an excellent Strategic Decision Support System for asset design or overhaul.
9	BridgeLCC - Life-cycle costing software for preliminary bridge design, is a user-friendly software developed by the National Institute of Standards and Technology (NIST) to help **bridge engineers** assess the cost effectiveness of new, alternative **construction materials**.	https://www.nist.gov/services-resources/software/bridgelcc [19]	BridgeLCC is specifically tailored for comparing new and conventional bridge materials - for example, high-performance concrete versus conventional concrete, but works equally well when analyzing alternative conventional materials. The software uses a life-cycle costing methodology based on both ASTM standard E 917 and a cost classification developed at NIST.	Tools for Designing Cost-Effective Building Systems. The Office of Applied Economics develops economic methods and software to aid industry in evaluating the cost effectiveness of new-technology construction materials, "green" building materials, building energy systems, and other construction processes. BridgeLCC 2.0 supports this effort by helping engineers to **evaluate bridge-related design decisions.**
10	LCC Software Sassda has developed a world-first app for **stainless steel's** ability to ensure far lower overall LCC.	https://sassda.co.za/about-stainless/the-life-cycle-costing-of-stainless-steel/ [25]	Its ability to provide long-term performance with a minimum of downtime and cost associated with maintenance is determined by calculating the material's lifecycle costing (LCC), which is of particular importance to the **stainless-steel industry**.	The technique uses the standard accountancy principle of discounted cash flow, so that total costs incurred during a lifecycle period are reduced to present values. This allows a realistic comparison to be made.
11	Automate building life cycle cost calculations. Calculate costs from all life cycle stages. Compare and choose the most eco-friendly and cost-efficient design. Submit LCC results to earn certification credits.	https://www.oneclicklca.com/construction/life-cycle-costing-software/ [21]	The cost data is available for all main **construction materials** in the One Click LCA database. The database production process has used various cost databases, including the Neubau Baupreise Kompakt; Statistische Baupreise für Positionen mit Kurzttexten (BKI) (2017) and the Spon's Architects' and Builders' Price Book (AECOM) (2017).	One Click LCA Life Cycle Costing tool is designed in line with EN 16627 and ISO 15686-5 standards. Results are reported based on the mandatory cost categories in the EN standard, including **construction**, **maintenance**, **operation**, and **end-of-life related costs.**
12	Assess capital costs for **constructions, systems&floor or ceiling materials** and prepare customised capital cost estimates at any stage of a project.	https://www.iesve.com/software/virtual-environment/applications/life-cycle-cost-analysis [15]	Perform Life Cycle Costing at any stage of the design process and easily incorporate costs for the whole life of the **building**.	Undertake Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and more through the partnership with One Click LCA.
13	Carrier Releases Free Life Cycle Cost Analysis Software to Compare **Chillers from Different Manufacturers.** PLV Pro provides a quick alternative to detailed energy modelling analyses.	https://www.carrier.com/carrier/en/worldwide/news/news-article/carrier-releases-free-life-cycle-cost-analysis-software-to-compare-chillers-from-different-manufacturers.html [6]	PLV Pro calculates custom part-load weighting factors and condenser water temperatures based on site-specific weather profiles, U.S. Department of Energy building occupancy profiles, chiller staging and **system design**. Criteria include geographical location, building type, quantity of chillers, chiller staging method, design temperatures and chiller plant capacity and design.	Carrier has introduced PLV Pro™, a new software tool to provide fast, easy life cycle cost analysis at no charge for water-cooled chillers from different **manufacturers**. Carrier is a part of Carrier Global Corporation (NYSE: CARR), the leading global provider of healthy, safe, sustainable and intelligent building and cold chain solutions.
14	LCCA and **Value Engineering** is an approach used to assess the total cost of owning a facility or running a project	https://corporatefinanceinstitute.com/resources/knowledge/finance/life-cycle-cost-analysis/ [7]	Rigorous modelling based on LCCA incorporates value engineering so that a project's cost outline can lower expenditures by a huge margin. The procedures are done through a series of tests on the cost of operation.	Life cycle cost analysis can be used to assess different **infrastructural sectors** such as **rail** and **urban transport**, **airports**, **highways**, and ITS, as well as ports and **industrial infrastructure**.
15	BSRIA is involved in 6 out of the 10 work packages within the CILECCTA project	https://www.bsria.com/uk/test-research/research/cileccta/ [4]	CILECCTA is a **large-scale integrating collaborative projects** co-financed by the European Commission under the 7th Framework Programme, Cooperation Work Programme.	CILECCTA has 19 participants from 8 EU. The project has started in 2009 and was active for 4 years. The software developed fully LCC analysis, compatible with codified Price Banks (PBs), as well as Life Cycle Inventories (LCIs), across Europe.
16	Life Cycle Costing GaBi enables to track different cost factors related with a **process or flow throughout the life cycle.**	https://gabi.sphera.com/software/gabi-software/gabi/functionalities/life-cycle-costing/ [13]	The Life Cycle Assessment solution, GaBi Software, offers the globally broadest compilation of high quality and annually updated databases to suit the data needs. It is key in various costs, such as for **raw materials** or **energy**, personnel, **operating machines**, overheads, **packaging** or	All individual GaBi datasets are comparable by using consistent methods and boundaries as well as common background data and models in their construction. GaBi is enable to display expenses across the life cycle.

			transport.	
17	The National Institute of Standards and Technology (NIST) developed the Building Life Cycle Cost (BLCC) to provide computational support for the analysis of capital investments in buildings. They include BLCC, the Energy Escalation Rate Calculator and Handbook 135.	https://www.energy.gov/eere/femp/building-life-cycle-cost-programs [10]	BLCC version 5_3_22 contains the following modules: FEMP Analysis, Energy Project, Federal Analysis, Financed Project Office of Management and Budget Analysis, MILCON Analysis, **Energy and Non-Energy** Project, Energy **Conservation Resilience** Investment Program. BLCC calculates comparative economic measures for alternative designs (net savings, savings-to-investment ratio, adjusted internal rate of return and years to payback).	BLCC conducts economic analyses by evaluating the relative cost effectiveness of alternative buildings and building-related systems or components. Typically, BLCC is used to evaluate alternative designs that have higher initial costs but lower operating costs over the project life than the lowest-initial-cost design.
18	Life Cycle Costing (LCC) - Business **modelling the whole life cycle of products and services**.	https://www.life-cycle-costing.de/ [18]	Life Cycle Costing (LCC) is an accounting approach, which **addresses the cost implications of a service or asset in a broad sense**. Because of this complete life cycle thinking, LCC is referred to as "womb to tomb" or "cradle to grave" approach.	LCC is often performed beforehand in order to estimate the total cost of ownership of several alternative solutions before irreversible decisions have been taken and the venture is progressed to far to be reverted.
19	This is a User Guide to the Life Cycle Costing Tool for **Green Public Procurement of Computers and Monitors**.	https://ec.europa.eu/environment/gpp/pdf/EC_LCC_computers_guide_final_updated_Mar2019.pdf [11]	The purpose of the tool is to encourage and facilitate the wide application of life cycle costing (LCC) among public authorities in the EU. The tool has been designed to be used during tendering processes.	The guide provides the key aspects to consider when using LCC in public procurement, especially during the preparatory and tendering stages. It introduces briefly the main sections and elements of the LCC tool itself.
20	The CRAVEzero spreadsheet is a comprehensive tool to perform life-cycle cost analysis for nZEBs.	https://www.cravezero.eu/pboard/Downloads/LCCTool.htm [8]	The data collection is organized following as a base reference the LCC structure introduced by the Standard ISO 15686-5:2017 (**Buildings and constructed assets- Service life planning**, Part 5: Life-cycle costing). The source used to structure the construction costs is the European Code of Measurement, elaborated by the European Committee of the Construction Economists.	The LCC tool is composed by 6 sheets "Project information", "WLC", "Construction cost", "Calc maintenance", "Results" and "Charts. The first 4 sheets are devoted to receive input values, the last 2 display the results of the calculation.
21	Life Cycle Costing in SimaPro, by Andreas Ciroth, Juliane Franze, GreenDeltaTC Berlin, August 2009	https://pre-sustainability.com/files/2020/09/LCCinSimaPro_english.pdf [24]	LCC has a long tradition in **industry**, especially for those products that have a long life time and/or high **maintenance**, use or disposal costs. Life Cycle Costs are a way to demonstrate that more effort for the production "pays off" by reduced use or maintenance costs or disposal costs.	Conducting an LCC study in SimaPro - new assessment method needs to be created, and then populated with damage categories, subcategories, and flows or "substances" that express economic impacts. Then, these economic impacts need to be assigned to processes where they occur. After, LCC can be calculated, and the result be displayed in Sankey diagram and in the other interpretation features that SimaPro offers.

Source: Own selection.

In Table 2, a number of 21 software that can be applied to use the LCCA method have been listed and presented.

Most of them are used in industry, manufacturing, production, others in consulting, in research or even in the education sector.

The essential elements for identifying the utility and web allocation for each identified software were introduced, as well as a short description. Because of the field specificities, only some of them can be performed in the agriculture sector (i.e. simaPro, Gabi, openLCA).

CONCLUSIONS

As conclusion for the findings of the paper, we have tried to summarize the uses of the LCCA method, the constrains and errors that could occurred and possible results. The LCCA methodology, although it is more often used in other sectors than in agriculture, it has also demonstrated its effectiveness in evaluating the results of horticulture processes, for example. Such a method can be used successfully in sizing the production processes in an orchard and exploring the options regarding the costs involved in its entire life span, from the establishment of the plantation until its discharge. Also, the design of alternative results over the life cycle of the project should be presented as feasible solutions of the method, together with the level of the detail that the solutions investigated have had. Thus, using the LCCA method in the studies covering the agricultural systems will bring more emphasize, precision and the possibility to make choice among feasible selections. The constant use of this method in system analysis will bring accuracy and the possibility of having a more advantageous process in terms of costs.

ACKNOWLEDGEMENTS

This work was supported by a grant of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, project number 1260/2021/ ECO-LCA 0016, within IPC 2021.

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