LIFE CYCLE COSTS FOR SUSTAINABLE BUILDINGS

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Abstract
The interest for sustainability, especially in construction, product quality and competitiveness is increasing the focus on aligning legislation and practices on the cost of building life cycles, a tool that underpins strategic decisions. For this purpose, well-defined but punctual practices already exist in countries such as Germany, Austria; such practices take into account specific national legislation. Yet, no of life cycle cost (LCC) calculation models could be identified in Romania.
The aim of this paper is to identify relevant aspects that are included as a basis for existing LCC calculation models and to make a proposal underlying a LCC calculation model tailored to the specific market in Romania.
In order to develop this model, a comparison is conducted, focusing on existing software models in Germany and Austria. Based on the advantages and disadvantages identified, taking into account the theoretical aspects of sustainability and LCC, the limitations related to the complexity of the models and the market specificity, we propose main elements which may fundament the development of a LCC calculation model adapted to the Romanian market requirements and specific regulations.

Keywords
Sustainability, Life cycle cost (LCC), facility management.

JEL Classification
M10, L86, R30

Introduction

The international trends in competitiveness and quality of products and services are redefined in national practices, which requires a national alignment to the international regulations. One of these aims the life cycle cost, which not only represents a necessity, it is also a support in strategic and investment decisions, especially in the construction field.
In recent decades, there has been a growing focus, both on national and international level, on the increased attention of service consumers to values such as competitiveness, transparency and the quality of services received. These values are promoted by harmonizing legislation within the European Community.
In the construction sector, in order to make the most accurate investment decisions, it is useful and necessary to have an overview of current and future costs.

Life cycle cost (LCC) analysis requires laborious work, as the results of the analysis should include information on cost variations by surface area, functional units, time, cost categories, etc. Interpretation of the results has to be done with much responsibility because the methods of calculating LCC, based on evaluations and assumptions, have a high degree of subjectivity. Parameters such as inflation rate, operational costs, etc. are the result of the estimates and hence the imprecise lack of precision that needs to be considered in making sustainable decisions (Mehedinţu & Postăvaru, 2016).

Life cycle cost and sustainability

The construction sector has a major impact on the environment. According to a study by The Chartered Institute of Building (The Chartered Institute of Building, 2011; Statistik Austria, 2015), more than 45% of the fossil fuel combustion energy is used for lighting, cooling and heating buildings, and another 5% for the construction of buildings, leading to major emissions of carbon dioxide (Dubina et al., 2010).

In order to implement the environmental principles and achieve significant results, it is necessary to evaluate construction and technical equipment throughout the life cycle. An appropriate tool is to analyze sustainability within facility management. Sustainable development is a continuous process throughout the building's life cycle, just as facility management is a continuous process of optimization.

In the sustainability discussion, the real estate sector is involved not only in the high consumption of resources and carbon dioxide emissions, but also in the high lifespan of buildings with high potential for economic influence. At the "Sustainable Building" conference in Oslo (Pettersen, 2002), concrete actions with clear methods and concrete criteria for implementing real estate sustainability were discussed.

By applying the principles of sustainability, not only sustainable planning and construction is pursued, but also an improvement in economic indicators, characterized mainly by optimizing life cycle costs. These aspects may reduce the operational costs and increase the construction costs, which is why it is useful a thorough analysis of the lifetime of building components in relation with decisions on the used materials, the associated costs and the environmental impact.

A sustainable building is one that uses energy, water or natural gas efficiently and provides a safe and productive interior environment. LCC analysis is primarily designed to identify a cost-effective design of the building, with building strategies throughout the life cycle of the building. The most effective solution is not always the most environmentally friendly, but capitalizing on technological progress, along with addressing development strategies from the design stage, can lead to a long-term balance (Stanford University Land and Buildings, 2005).

Calculation life cycle cost

According to ISO 14040:2006 life cycle is represented by "consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal" (ISO 14040:2006).

Hellerforth divides the phases of the life cycle into six steps, as can be seen in the figure no. 1 (Hellerforth, 2006):

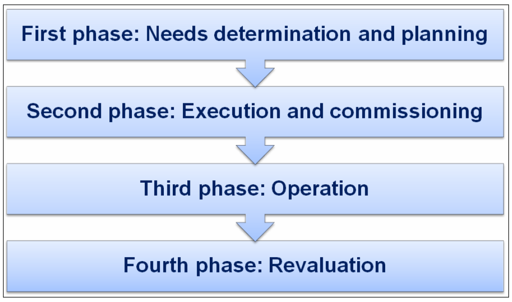

Fig. no. 1 Life cycle phases

Source: Hellerforth, 2006

The operational phase is actually the facility management, "an organizational function that integrates people, places and processes within the built environment to improve people's quality of life and productivity of the core business," according to the latest definition (ISO 41011: 2017).

There are country-specific approaches to the rules and the LCC analysis period. For example, in France it is considered appropriate to consider to analyze a building for 25, 30 or 50 years; in Sweden, the life cycle cost is calculated for a period of 60 years, similar to the approach from Switzerland [O.M.L.P.A.T., 1992; Crb., 2014); in Germany, the analysis period is limited to 50 years, according to the German official regulations and German Sustainable Building Council (DNGB) (Zimmermann, 2012; Rotermund & Nendza, 2011).

Many software for calculating LCC have been developed, such as GBTool (international), TQ-Tool, ABK-Lekos (Austria), BUBI, LEGEP, bauloop und baulocc, GaBi, GEMIS, ÖÖB (Germany). These programs work either with national databases or with their own data or with specific input data for each project. They take into account both costs and indicators for "environmental consumption," i.e. pollution of nature with carbon dioxide, sulfur dioxide, energy needs, primary energy content (total energy consumption for building material or component) consumption of raw materials, etc. In all software, separate economic and environmental aspects of buildings are issued.

In Romania, no nationally aligned model could be identified, only individual models of multinational companies. Under these circumstances, in the present research, we analyse a software model used in Germany and one used in Austria, presenting briefly how to work, strengths and weaknesses.

Methodology for analysis

In order to explore and identify relevant elements that are included as the basis for the LCC calculation models and to propose bases for models in Romania, we selected two most used and user-friendly software from the above list, from Germany and Austria. We made a descriptive analysis of the functionalities and data used for the two chosen. Practical simulations have been carried out to identify their strengths and weaknesses and to conduct a comparative analysis.

Variables related to legal and practical specificity of the construction and real estate sector are country-specific, and should be approached in specific modelling, which is beyond the purpose of the present research. Thus, as these aspects are not explored in the context of the present research, more in-depth research may be conducted further, aimed at providing more detailed specific model for Romania.

Comparison of two software for calculating the life cycle cost of a building

LEGEP is a German software that uses construction costs, energy requirements, future costs, and the ecology of a project (WEKA MEDIA GmbH & Co. KG., 2010). The program has a database specific to each of its modules. It is a support tool for designing, building, quantifying and evaluating new or existing buildings. The database contains a description of building elements according to DIN 276, their life cycle costs, according to DIN 18960 based on DGNB.

The energy needs for utilities (heating, hot water, electricity) and associated costs are determined based on the German EnEV 2009 (Energy Regulation) and EN 832. The environmental assessment is based on ISO 14040-44.

The database is hierarchically organized, ranging from building materials data, description of working processes, simple material layers, compound elements (e.g. windows) to macro elements (e.g. building objects). Each level has all the necessary cost, energy, flow and impact [211] data. The database with over 6,000 items is updated annually by a German architectural office - sir Ados (LEGEP-Software; König, 2011).

The user can define specific compositions, but this feature requires programming knowledge. Starting from price changes and interest rates, the static or dynamic method can be used to calculate costs using the net present value. Results can be rendered in graphical form, but they are less flexible.

The use of this program is recommended in the construction phase, when all the soft elements of the building are already known.

ABK-LEKOS software has a cost structure according to ÖNORM B 1801-1 and 1801-2, but it can be adapted to the requirements. The VAT rate also corresponds to the Austrian regulations. Valuation is based on inflation. The software has a database, according to the calculation models introduced by the manufacturer and the data provided by the BKI (Building Cost Information Center of the German Architects' Chamber).

Parameters such as costs, cost variations, frequencies, etc. must be entered manually by the user. Even new models and formulas can be entered and saved in the software.

The software is based on the multiplication of surfaces (and activity frequencies) with unit costs, percentage calculations, or direct costing of the final cost for certain cost groups. Compared to the "surface" variable, the utility costs are approximated. It uses the net present value method and the price and interest rate parameters can be changed manually by the user.

The results are presented as graphs according to the user's wish. The program has an affordable and flexible interface due to the option of entering the desired parameters, but it also presents functional disadvantages: it does not have a cancellation function, it cannot convert percentage values, it presents differences between the net and gross values, it does not recognize negative values, it does not make connections between the introduced surfaces, has major deviations of surface calculation.

For BKI prices, German VAT rate differs from the Austrian VAT rate (19% versus 20% in most cases).

The advantages and disadvantages of the two software programs are presented in table no. 1.

Based on the experience and analysis of the two software, as well as the GEFMA Handbook (Bernhold, 2017) costing information we identify and propose a number of relevant elements to consider when developing a model for LCC calculation for Romania. They can be classified into: economic and legislative elements, technical and facility management elements, elements related to the specifics of the building's operating period.

The economic and legislative aspects that need to be considered are: the life expectancy of the building, the variance of money over time (future risks, interest rates, probable inflation, exchange rates, etc.), the forecast of price fluctuations at national level given by the

National Statistics Institute, the evolution of the price of consumables, taxes, interest, and legislative constraints.

Table no. 1 Strengths and weaknesses of LEGEP and ABK-LEKOS software

	LEGEP	ABK-LEKOS
Strengths	- The menu, the interface are well structured and easy to use; - The possibility of exporting information as table or text; - Comprehensive database; - Easy comparison of projects; - Automatic calculation of average costs and average flows of utilities (electricity, gas, water) depending on the type and technical specifications of the building; - Detailed calculation of facility management costs based on working processes.	- To be used in the design phases; - Easy and quick introduction of values related to the technical requirements of the building; - Calculation of costs by the net present value method according to the expectations of real estate investors; - Calculation of costs according to official national inflation forecasts; - Clear representation of the results in electronic and physical form; - Numerous custom representation of results; - Flexible and transparent calculation mode; - Predefined calculus models; - Possibility of LCC calculation for new and modernised buildings;
Weaknesses	- Designed to be used exclusively for buildings in Germany; - Database according to German standards; - German prices updated annually; - Cannot be applied in incipient design phases because it requires detailed information about the building; - Does not automatically save the entered data; - Does not recognize incorrectly entered data (e.g., negative data); - Has low flexibility for user inputs or prices; - Is not flexible in presenting charts: cannot be personalized.	- Specialized on office buildings with medium standards; - Applicable to office buildings, dwellings, schools; - For variations, manual data entry is required; - Cost structure according to Austrian classification; - Does not have plausibility control (does not recognize negative values, typing errors, etc.); - It has errors in calculating VAT; - Report activity errors; - Has software errors that can be corrected by restarting the program; - Does not have a return function to previous values.

The technical and facility management elements are based on the specificity of the building, the climatic location, the technical data of the equipment and the manufacturer's estimations, considering the ideal consumption situation, the technical characteristics of the building and the specifics of the building installations (e.g. sockets, lighting fixtures, equipment, etc.), the need to replace the equipment with lower life cycles, annual intervention frequencies, hourly fees, the costs of accessories and consumables, operating authorizations, the methods envisaged for the planning of construction works, the timing of these works, materials/consumables for facility management activities performed during the building's operation phase, season and outside and inside temperatures; losses or energy gains; yearly cooling and heating season and climatic data.

Regarding the elements related to the specificity of the building's operating period, the following should be taken into account: the number of occupants of the building and the period of operation of the building (important for the determination of electricity and water consumption); occupant's behavior; the specific nature of the work performed inside the building.

Conclusions and recommendations

Enabling measuring for sustainability, especially in construction, product quality and competitiveness should be taken into account and strengthened, with focus on aligning legislation and practices on the cost of building life cycles, a tool that underpins strategic decisions. Exploring practices in other countries, such as Germany and Austria, with comparative analysis of software approaches for life cost calculations for building, in countries, provided insight into elements that should be taken into account in approaching LCC modeling in Romania. Further research may be conducted in exploring and developing life cycle cost (LCC) calculation models could be identified in Romania.

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