Life Cycle Costing of Public Construction Projects

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Abstract. The purpose of this paper is to highlight the role of life cycle costing in the preparation phase of public construction projects. Life cycle costing is a method of economic analysis directed at all costs related to constructing, operating, and maintaining a construction project over a defined period of time. In the early phase of construction projects, an enormous benefit in life cycle costing can be achieved. The commonly used construction cost minimization approach should be substituted for life cycle cost optimization. In order to gain the maximum value for money, all costs incurred over the whole life span must be estimated. The optimization of the life cycle costs of a construction project is essential for a complex decision making process. All taken into consideration, the solution with the minimum value of life cycle costs can be chosen. Public investors are required to meet the objectives of sustainable building, and as a group they face limited financial resources and frequently a very strict institutional framework including procurement procedures. The quantification of life cycle costs, when deciding on a construction project, is required by the public sector in the Czech Republic. In addition, the estimated amount of life cycle costs has become a criterion in public tenders. The paper summarizes experience in building design valuation in terms of these life cycle costs.

1. Introduction
The activities of public investors and their decisions should be carried through taking into consideration the public interest and the need to spend public funds efficiently. The tender price is often the most important factor determining the award of a public procurement contract. Public investors may argue that the cheapest bid provides budgetary savings. However, the best value for money is not always achieved by accepting the cheapest bid. Budgetary savings can be accomplished originally in relation to the tender price, but additional costs will be generated by the use of the buildings. Additional costs are associated, in particular, with operational and maintenance costs. In addition to these direct costs, the use of the buildings may have an impact on the environment, which will possibly result in further investments or charges. As a consequence, from an economic viewpoint, the most reasonable way forward is to deal with all of the costs that will be incurred during the life span of buildings in order to determine the least expensive bid in actuality. Life cycle costing is a methodology for calculating all of the costs over the life cycle of buildings. Public investors are becoming far more aware of the fact that life cycle costs represent a better indicator of value for money than the tender price alone. For this reason, the European Commission has supported this approach for several years. Moreover, life cycle costing approaches to public procurement also encourage sustainable development.
2. Literature review
Buildings as the productive outcome of construction projects are characterized by long lifespan and high costs. This is the reason why all decisions connected with a construction project have long-term and significant impact [1]. Construction project investors often have focused simply on the acquisition costs, when they were about to make decisions on such matters as the building design, facilities, fittings. They often neglected future operation and maintenance costs [2]. A cost-inefficient variant could thus be selected. Life cycle costs (LCC) in general consist of an initial investment (usually construction costs) and the follow-on costs (ordinary payments, i.e. energy, utilities, cleaning and maintenance, irregular costs for replacement), while some life cycle costing methods also include the costs of demolition [3].

Life cycle costing is a method assisting an effort to estimate the total cost of ownership. The method is able to help in making decisions within building investment projects [4]. Life cycle costing is particularly useful for estimating total costs at the early stage of a project [5].

In fact, the capability to influence the outcomes of whole life ownership is enormous during the design phase. The types of material specified, the quality of the design and the contracting method have to be chosen with relevance directly to operation and maintenance costs. In so doing, the used procurement methods may have implications and indeed great influence on life cycle costs. Operating, maintenance and replacement costs of buildings make up more than 80% of total life cycle costs [6]. It is well documented that the majority of decisions regarding operating, maintenance and replacement costs are predetermined at the design stage. The opportunities to modify or influence decisions about operating, maintenance and rehabilitation costs in reality decrease as projects progress. Current LCC methods and their problems are described in [7].

3. Life cycle costing
According to the International Standard [8], life cycle costing is a valuable technique that is used for predicting and assessing the cost performance of buildings. Life cycle costing is one form of analysis for determining whether a project meets the client’s performance requirements. Life cycle costs (LCC) mean involving all of the costs deriving from the use of buildings during their entire life span. The LCC methodology is a tool for evaluating these costs over time. Its main goal is to assess the various tenders, where those tenders differ not only in their tender price but also in their operational and maintenance costs.

It is frequently debated that LCC is only advantageous in the case of extremely complicated contracts, such as the design and construction of a nuclear power plant or such like. However, even for less complicated contracts, the LCC approach is appropriate and does lead to a different result than when the tender price is the only criterion taken into consideration.

Using an LCC methodology could be a significant gain for public investors. The use of an LCC methodology can save money by both providing better forecasting and optimising future costs. In addition, it may support local/global sustainable development. All considered, the LCC approach provides the chance not only to obtain but manifestly demonstrate better value for money in a wide variety of projects [9].

3.1. Life cycle costs
Life Cycle Costs (LCC) represent the overall costs being spent during the building’s whole life cycle. Their structure:

- Investment costs (purchase price or tender price).
- Operating costs (consumption of energy, and other resources).
- Maintenance costs (costs of components that have to be periodically replaced).
- End-of-life costs (decommissioning and disposal) or Residual value of constructed asset (resale value).
3.2. Environmental approach

An environmental LCC methodology takes into consideration not only the main cost categories (investment costs, operating costs, maintenance cost, end-of-life costs), but also external environmental costs. The environmental impact may carry consequential costs for society. In general, constructed buildings, materials and products may have environmental impacts. The processes of manufacture, transport, assembly/disassembly, maintenance and disposal linked to buildings result, for example, in emission of greenhouse gases. Subsequently, significant investment will be needed to neutralize these consequences in the future. Calculation should include the costs of greenhouse gas emissions calculated using cumulated carbon costs for the analysed period (through prices of emission allowances). The LCC methodology makes the evaluation of costs in mitigating/reducing environmental impacts possible. As a result, the best value solution could be identified from both economic and environmental perspectives [9].

Energy performance contracting is the innovative financial instrument used to reduce energy consumption and the subsequent costs in customers’ buildings. With energy performance contracting, the main source of payment for the energy saving measures is the actual saving on energy consumption (or running energy systems) achieved by measures.

3.3. Legislative background

According to the 2004 Public Sector Directive (2004/18/EC) [10] a public investor could award a public contract by using either the lowest-price criterion or the most economically advantageous tender criterion. The following 2014 Public Sector Directive (2014/24/EU) [11] revised this concept and put greater emphasis on the evaluation of criteria other than only the bid price. According to such Directives, the public investor should base the award of public contracts on the most economically advantageous tender. The definition of the most economically advantageous tender has been altered by stressing that value for money symbolises a wider concept - the best price-quality ratio. According to article 92, the best price-quality ratio from the point of view of the public investor shall be selected on the basis of price or cost, using a cost effectiveness approach, such as life-cycle costing. The Directive provides a list of costs that might be taken into account by the public investor. Both direct costs (acquisition, use, maintenance and end of life) and environmental costs are included. Environmental costs must be quantified in monetary terms.

As stated in Directive [11] it is important to support the potential of public procurement to achieve the objectives of the Europe 2020 strategy for smart, sustainable and inclusive growth. In this context, it should be kept in mind that public procurement is crucial to driving innovation.

In the Czech Republic, according to the Act on Public Procurement (134/2016 Coll.), Section 117, [12] life cycle costing shall cover the tender price and may cover costs borne by the contracting authority or other users in the course of the life cycle of the subject-matter of the public contract, which may then include cover for, but not limited to, other costs relating to acquisition, costs relating to use of the subject-matter of the public contract, maintenance costs, or end of life costs, or costs imputed to environmental externalities linked to the subject-matter of the public contract at any time during its life cycle, provided their monetary value can be determined; such costs may include the cost of emissions of greenhouse gases and of other pollutant emissions and other climate change mitigation costs.

The method used for the assessment of life-cycle costs is described in general. As stated in Section 118 (134/2016 Coll.) [12], where the contracting authority assesses tenders using a life cycle costing approach, it shall indicate in the procurement documents the data to be provided by the participants and the method which the contracting authority will use to determine the life cycle costing on the basis of such data. To calculate the environmental costs, the contracting authority shall use a method that is based on objectively verifiable and non-discriminatory criteria, accessible to all tenderers, and based on data that can be provided by the tenderers with reasonable effort. The government may issue a decree setting out common methods used for the assessment of the life cycle costs and the scope of their use.
4. Application of LCC methodology in practice

Even if the idea of life cycle costing is understood in theory, its utilization seems to be actually a rather difficult task. The public investor has to analyse if an LCC approach is appropriate for the procurement task. Where an LCC methodology is suitable, the public investor should create a team of specialist staff, with necessary expertise, who will be responsible for procurement using LCC.

Any LCC methodology must be developed so as to be suitable to the specific characteristics of the building that the public investor plans to obtain. The scope and complexity of the LCC methodology should mirror the complexity of the building project itself, the capability of estimating future costs, and the importance of future costs for decision making. The following issues must be considered:

- Types of costs and their relevance.
- Data availability and reliability.
- Period of analysis.
- Method of economic evaluation of future costs.

Many assumptions influencing the result of the tender evaluation are made within LCC analysis. The target of the LCC analysis is to create an acceptable approximation of real costs. It is essential that all assumptions are clearly stated in the tender documents and that the evaluating method is described in detail.

4.1. A Performance-based concept

The public investor should prescribe the technical specifications in terms of performance characteristics, targeting primarily on the requested outcome (a building). This performance-based concept will enable the public investor to determine requirements for consideration of life cycle costs and the environment. Those making tenders have the opportunity to suggest the manner of fulfilling these requirements. The submission of variants is a natural expectation.

For illustration, the tender documents should not describe in great detail the air conditioning systems and insulation. The requirement of keeping the building at a temperature of 20 °C when the temperature outside is between minus 10 °C and 32 °C is defined instead. The bid price offered by one tenderer may be higher than that of another tenderer, but the life cycle costs of the designed building may be lower due to better insulation, air circulation systems rather than air conditioning.

4.2. Data availability and reliability

The life cycle costs calculation involves some uncertainty as to the future costs. The analysis may be founded on historical or benchmark data or on comparable cost-in-use data. Depending on the tender case, some costs may be significant while others are entirely insignificant. The crucial question is which categories of costs are relevant for LCC assessment of the building.

For procurement of a building, with a long life span, the probability of replacement of facilities and fittings is high. Taking replacement costs into account is very important. A cheap facility, which will have been many times replaced over the life span of building, may cause higher costs than an expensive long-life facility. Replacement costs of essential facilities have to be included in the LCC calculation. Tenderers should be requested to specify the replacement costs for an analysed period.

Operating costs, which include consumption of energy, are the cost category highly recommended for LCC assessment [13]. It is difficult to predict correctly some costs over a long period, for example cost of 1 kWh of electricity in 2040. However, the costs linked with electricity consumption should be included in the LCC assessment. By providing an electricity unit price in the tender documents the public investor ensures common standard assessment. Tenderers should be requested for information about electricity consumption of the designed building during the analysed period.

4.3. Period of analysis

The actual given period of life cycle cost analysis is a significant determinant of operational and maintenance cost evaluation. A long period of analysis (30 to 50 years) is usually chosen for investment
decisions in the public sector. The benefits from the reduced energy consumption are stronger as the period lengthens. In contradistinction, maintenance costs increase.

4.4. Method of economic evaluation of future costs

Interest rates are significant for the LCC methodology for buildings. Future costs are not “worth” as much as costs that are presently incurred, because financial assets are expected to grow over time. This needs to be taken into consideration. Application of a discount rate to future costs is a common way. This discount rate gives each cost a net present value (NPV), which allows a comparison between present costs and future costs. The discount rate applied may have a substantial influence on the result of the life cycle analysis. Selection of a correct rate is crucial. National treasuries may determine the discount rate for public sector projects and the rate is usually between 3 % and 5 %.

5. Case study

The subject-case of a public contract is procurement of the SAO's headquarters located in Prague, and the detailed design of a building and construction works are required. In order to evaluate the economic advantages of a tender on the basis of quality, the contracting authority defined 3 evaluation criteria:

- Tender price.
- Life cycle cost.
- Quality of team.

The LCC methodology has been designed to calculate the crucial operating and replacement costs for the design of the SAO's headquarters over a 30 year period. The methodology is intended to be used in the procurement procedure for the Design & Build Contractor of the SAO's headquarters, as a part of the tender documents.

5.1. Elaboration of the methodology

The basis for the methodology worked out was consultation with the designers of the building and the contracting authority. This consultation resulted in the definition of the assessed crucial facilities and fittings, which are supposed to have a significant impact to both operating and replacement costs of the designed building. The approach to documentation of facilities and fittings parameters was defined.

On the basis of the project documentation for the building permit and the energy performance certificate of the designed building, a model of the building was created in the “National Calculation Tool” (NKN) software. This model will be used as a tool for an energy performance calculation for each bid.

The life cycle cost calculator was created in MC Excel. It is composed of a National Calculation Tool (NKN) and a costing tool.

5.2. Relevant costs

The relevant costs for a life cycle cost calculation of the designed building were identified. For the purpose of awarding the contract, life cycle costs are calculated as the sum of the energy costs (as the most significant part of operating costs) and the costs of replacement and maintenance of the selected crucial facilities. The 0% discount value was applied (upon the client’s request). The cost of building acquisition (tender price) is not included in the LCC calculation as it is evaluated separately. Other costs are supposed to be comparable for all tenders so will reach the same values and thus irrelevant for life cycle calculation in this case.

The life cycle cost breakdown is as follows:

- Operating costs (energy costs, excluding VAT, over a period of 30 years).
- Replacement costs for 13 components (facilities and fittings), maintenance costs for 4 components, all excluding VAT, over a 30 year period.
5.3. **Operating costs**

Inputs for operating cost calculation are key indicators of building envelope parameters and key parameters for technical systems (facilities, fittings) that are crucial for assessing the energy performance of a building. The energy consumption of the designed solution is calculated in the National Calculation Tool (NKN), which is the part of the LCC tool. The energy consumption (energy supplied to the building) is multiplied by a fixed unit price of energy. The tenderer is able to calculate the energy demand of his alternative designs in the NKN tool and choose the optimum solution.

5.4. **Replacement and maintenance costs**

Inputs for replacement and maintenance cost calculation of each component are:

- Maintenance costs per year (excluding VAT).
- Acquisition costs (excluding VAT).
- Life span.

From these inputs, the replacement and maintenance costs for the selected crucial components (facilities, fittings) are calculated. The component cost data is used to calculate the replacement costs. For each of the components to be assessed, the contracting authority defined a maximum service life in tender documents. To determine the maximum usable life span, the underlying proper life value of the component was taken as a basis.

6. **Conclusion**

In conclusion, public investors should be precise and pragmatic when preparing parameters of life cycle cost calculation. Incorrect assumptions about cost, discount rate or period of analysis could result in an adverse or inferior economic outcome.

To support a transparent basis for comparing tenders, the cost assumptions must be declared in the tender documents. Thereafter, all can consider the same parameters during the preparation of their tenders.

In the European Union it is considered of maximum importance to utilize the potential of public procurement so as to achieve the objectives of the Europe 2020 strategy for smart, sustainable and inclusive growth. Together with other legal and practical means, LCC methodologies serve as tools that could assist in reaching the strategic goals. Cost estimation methods with the use of Building Information Modelling (BIM) in construction projects could be helpful for quantification of construction projects production and for following cost estimation. [14].

7. **Recommendation**

It is vital to assure that the cost assumptions of the winning tender are checked during the life span of a building or during the evaluated time period. The main aspect of the LCC methodology is the great influence of future costs. Therefore failure to meet the commitments indicated in tender must be seen as a failure to fulfil the contractual obligations. If the energy consumption were higher than the consumption indicated in the tender, the public investor would incur additional costs due to the difference between what the contractor had promised and what had to be paid. The contract drafter should include specific contractual clauses, such as the payment of damages for poor performance, in order to protect the public investor. In some cases, mainly if the contractor remains responsible for operational and maintenance activities, the risk of future costs may be transferred to the contractors.

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