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Carolina Colli, Alain Bataille, Emmanuel Antczak

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Whole-Life Costing of a French Single-Family House Refurbishment: the “Bat-Eco2” case study

C Colli¹, A Bataille¹, E Antczak¹

¹Laboratory of Civil Engineering and Environment, LGCgE, Université d’Artois, Pôle de Béthune, Faculté des Sciences Appliquées, Technoparc Futura, 62 400 Béthune, France

carolina_darochacolli@ens.univ-artois.fr

Abstract. Bat-Eco 2 is a research project on building refurbishment life cycle assessment (LCA) and whole-life costing (WLC). The project’s goal is to contribute to the development of a tool to help decision-making on refurbishment solutions, considering the environmental aspects along with the economic ones. This project has been split in four steps: (i) LCA of a standard single-family house refurbishment built in 1939 and located in Libercourt, Hauts-de-France; (ii) WLC of the same case study; (iii) crossing of LCA results with WLC ones; (iv) simplified tool specification in agreement with these results. This paper presents the WLC methodological choices and the corresponding WLC results. The WLC methodology complies with the ISO 15686-5. It details the refurbishment life cycle stages in compliance with the EN 15 978. The main choices are presented, i.e. system boundaries, economic rates, present costs for each life cycle stage, building residual value. Results enable to enumerate economic hotspots for the case study of this single-family house refurbishment. The whole-life costing is calculated using excel sheets, considering economic data from the social landlord Maison & Cités, house owner of the study case.

1. Introduction

The French building stock is composed of more than 65% of buildings constructed before 1975[1], hence following no thermal regulation. According to the recent plan of thermal refurbishment in France[2], 500 000 housings per year must be refurbished.

The refurbishments, basically, consider the investment costs in order to help decision makers[3]. However, this investment costs are not representative of the whole building life costing. Still, there are many studies considering economic sustainability[4–8], but without taking into account the whole-life costing (WLC) of a building (products, construction or refurbishment, services during lifetime and end-of-life). The whole-life costing is the sole methodology which considers all costs along the building lifetime, and thus it is more pertinent to represent the economic aspect of a building[9].

2. Goal and Scope

The current work uses specific methodological choices concerning indicators, economic parameters, system boundaries and rates. The goal of this paper is to present and to discuss the WLC results. A



sensitivity analysis of the WLC assessment will supplement the analysis. This investigation was carried out on a typical single-family semi-detached house refurbishment located in the North of France.

This project takes into account the cost of financing the investment, as well as the externalities associated to (i) the tenant solvency and (ii) the vacancy rate. This corresponds to a WLC approach. The income is not considered in the study

This work is part of the Bat-Eco2 project, a regional project aiming at specifying a tool in order to support decision-making for different refurbishment choices, combining environmental and economic criteria.

3. Method

The economic assessment used in the present work is the WLC applied to a dwelling refurbishment. It takes into consideration all the costs of a building period of analysis. This methodology includes the life cycle costing (LCC) plus the externalities, the non-construction costs and the income. For a building, the LCC sums up the costs of construction, the operation costs, the maintenance costs and the end-of-life costs[3]. The methodology follows the standard ISO 15 686-5:2008[10] and the boundaries are represented in Fig. 1.

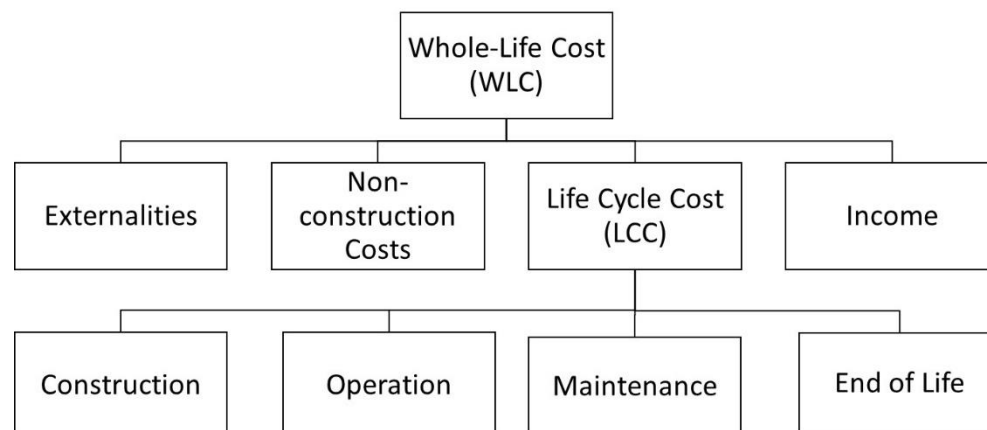


Figure 1: System Boundaries
Source: ISO 15 686-5

The “Construction” aspect corresponds here to the refurbishment and its initial investment. The operation consists of the rents, the insurances, the energy and water consumptions and the living taxes. The maintenance is composed of the replacements during the building period of analysis and the expected/planned maintenances. The end-of-life costs represent (i) demolition or deconstruction, (ii) waste transport; (iii) products and equipment treatment or disposal.

The WLC methodology is quite similar to that of life cycle assessment (LCA). After defining the goals and the system boundaries, an inventory is established with the detailed costs for each step as mentioned before. The results are then summed up.

The income is not considered in this analysis. Regarding the non-construction costs, only the cost of financing the investment is taken into account; and regarding the externalities, only the vacancy and unpaid rent rates are taken into account.

The environmental cost impacts are not taken into account on the operation step. This study focus only on the economic assessment, an environmental assessment has already been done. The interaction between environmental and economic assessments is under work.

4. Case Study and Methodological Choices

This paper presents the WLC of a refurbishment operation of a single-family house from 1939 located in Libercourt, North of France. The house is a semi-detached dwelling on a area of 300 square meters. The living area after refurbishment operation is 59 square meters.

The dwelling is composed of two bedrooms, one living room, one kitchen, one toilet, one bathroom and one small cellar.

The case study is part of the social landlord Maisons & Cités Soginorpa. It is one of their typical energy efficiency refurbishment.

This study is presented as part of the Bat-Eco2 research project, aiming at supporting decision-making on different refurbishment choices.

The partners of this project are Artois University, Lille 1 University, CD2E (Centre de Développement des Eco-Entreprises, a public agency), CIRAIG (Centre international de référence sur le cycle de vie des produits, procédés et services, a Canadian Research Center on Life Cycle Assessment), CROA (Conseil Régional de l'Ordre des Architectes), NJC Economie (a French firm dealing with economics in building) and the landlord Maisons & Cités Soginorpa.

The WLC methodological choices are presented hereafter.

4.1. Period of Analysis

The economic period of analysis depends on the profitable time of the building[3]. If the estimated period of analysis of the building during a life cycle assessment (LCA) is of 50 years, the one used in the WLCs is normally lower. The standard ISO 15 686-5 suggests not exceeding a 100-year period of analysis for WLC.

However, many studies consider a lower period: between 25 and 40 years[11], arguing that any future costs after year 40 are insignificant. Another explanation is the increasing uncertainty linked to the extension of a considered period.[12] The longer the considered period, the more uncertain the evolution of economic taxes and rates. As a matter of consequence, the reliability of economic results decreases as the considered period of analysis increases. For this case study, the considered French building period of analysis is usually 50 years nowadays. Taking into account this duration, the period of analysis is also of 50 years for the present WLC. This complies with the requirement given by the standard, i.e. less than 100 years.

4.2. Real versus Nominal Value

In economic terms, the values can be expressed in two different ways, due to the existence of a monetary value fluctuation in time due to the inflation rate. Thus the economic assessment results can be expressed in real or nominal values. The real one presents the values without inflation effects. The nominal one considers inflation effects and stands for the current value of products.

Considering real or nominal values, it is fundamental to define a reference year in order to calculate the present value according to the future values using real or nominal discount rates, respectively. For this case study, the real value has been chosen in order not to take into account the fluctuations in product costs.

4.3. Inflation Rate

The inflation rate indicates the variation in product prices. This rate is normally computed from observed variations of previous years. However, price fluctuation of previous years is not necessarily helpful to predict the future ones. Thus, the results obtained for the inflation rate can be highly debatable.

In terms of economic assessments, it must be defined whether one chooses to express the results in real value or in nominal one. According to the choice, the inflation rate is not taken into account.

4.4. Discount Rate

The discount rate is the expression of present value preference instead of future value. This discount rate can be drawn, as the inflation rate, from previous year variations.

In order to lower the uncertainties of this study, a set of different real discount rates were allocated such as replacements discount rate, maintenance discount rate and living tax discount rates.

4.5. Economic Data

The economic data related to the construction products and equipment, as well as the data regarding the energy and water prices, maintenance and replacements, end-of-life must be considered in the whole-life costing approach.

These data can be generic ones, possessing a degree of uncertainty, but, if available, they are specific data. In the French context, there is a generic economic database named Batiprix [13]. It is updated each year and contains data related to prices of each construction product and of each equipment, as well as prices of implementation.

For this case study, specific data were collected from the project team social landlord.

4.6. System Boundaries

The analysis considered the externalities, non-construction costs and the LCC, according to the standard ISO 15686-5 [10]. The LCC phases have been fully considered. However, no cost spent by the tenant is computed, meaning no energy and no water consumption costs during the use phase. Indeed, this case study is analysed in order to produce data to help the decision-making before refurbishment operation.

The costs included in this WLC are rent; externalities due to unpaid rent and vacancy rates; initial investment; cost of financing; planned replacements; planned maintenances; property taxes and end-of-life.

4.7. Economic Indicators

The standard ISO 15686-5 proposes the use of the net present value (NPV) or net present cost (NPC). This net present value represents the sum of all costs discounted for a reference year. The equation of NPV is presented below.

$$X_{NPV} = \sum_{n=1}^p \frac{C_n}{(1+d)^n}$$

Where

C is the cost of year n, q is the discount rate, d is the real discount rate per year, n is the number of years between the reference year and the occurrence of the cost, and p is the period of analysis.

Many studies consider the NPV as the economic indicator [5–7,14,15], but there is also some dealing with the future value [11,16].

The economic indicator used in this WLC is the NPV and the discounted payback time.

The discounted payback time is the time to recover the costs of investment in present values. In this paper, the payback time is calculated as the ratio between the initial investment and the net cash flow per period.

5. Results

The economic results computed from the case study details and methodology are shown in Fig. 2.

The values presented in Fig. 2 are relative values, for the sake of the landlord economic data confidentiality. The percentages are calculated considering the total rent as 100% and the corresponding percentage debts for initial investment, replacement, maintenance, property tax and end-of-life.

The whole-life costing includes the entire costs during the building period of analysis. Thus, some important economic hotspots are highlighted, such as, the maintenance and replacements costs, which represent 17% of the expenses altogether.

The costs associated with the end-of-life are very low, thus not clearly visible in Fig. 2. These costs regroup the aspects of demolition, transport and waste disposal at the end of the period of analysis, i.e. 50 years.

In order to complete the current analysis, a sensitivity analysis has been carried out and is presented hereafter.

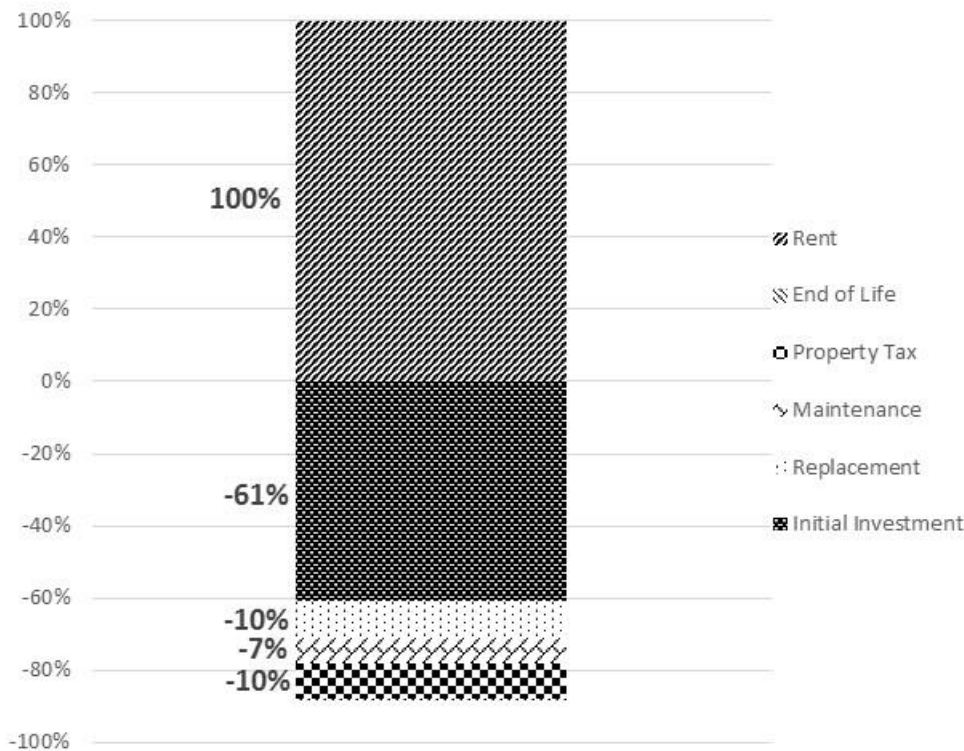


Figure 2: Relative Net Present Value according to different steps on the case study lifecycle (relative results are presented from top to bottom according to the legend)

6. Sensitivity Analysis

6.1. Period of Analysis

The building period of analysis for this case study is 50 years. In order to analyse the sensitivity of the results to this information, two other periods were considered: 30 and 80 years. All maintenances and replacements were then taken into account. No other extended new refurbishment was considered for the longer period. The results of this analysis are shown in Table 1. The relative values are all given in relation to the reference scenario (50-year-period).

Table 1. Analysis Results according to building period of analysis (reference period of 50 years)

Period of analysis (years)	NPV (%)	Discounted Payback time
30	-53 %	-
50	100%	41
80	180%	41

The 2nd result is as the reference and the others were calculated in accordance. The NPV of 30 years building period is negative and thus, the percentage is equal to (-) 53% of the reference scenario with 50 years building period of analysis.

The payback time is of 41 years for both 50 and 80 years periods. This 41 years payback-time is out of reach when the period of analysis is of 30 years.

6.2. Loan period

The variation of the loan period does not give very different NPV as can be seen from Table 2. The payback time varies from 35 to 45 years, depending on the loan period.

Table 2. Analysis Results according to Loan Period

Loan Period	NPV (%)	Discounted Payback time
15	137 %	35
20	100 %	41
25	61 %	45

6.3. Discount Rates

Discount rates estimations are drawn from past values. These rates are one of the keys to the assessment reliability. The sensitivity analysis considers variations of the following rates: loan, maintenance, replacement, property tax and rent. The results are shown in Table 3.

Table 3. Analysis Results according to Discount Rates

Discount Rate Values	NPV	Discounted Payback time
Loan Discount Rate		
2%	175 %	33
4.10%	100 %	41
6%	25 %	48
Maintenance Discount Rate		
0.5%	76 %	43
1.6%	100 %	41
3%	121 %	37
Replacement Discount Rate		
0.5%	54 %	45
1.8%	100 %	41
3.1%	131 %	37
Property Tax Discount Rate		
1.2%	79 %	43
2.2%	100 %	41
3.2%	116 %	37
Rent Discount Rate		
1%	329 %	31
2%	100 %	41
3%	-68 %	-

6.4. Rental vacancy and unpaid rent rates

For this case study, a rental vacancy rate and an unpaid rent rate of respectively 1.1% and 0.9% are considered. These rates are related to the attractiveness of the houses and the capacity to pay the rent. The house used in this case study is part of the stock of Maisons & Cités, which is composed of social houses and are occupied by modest families. The thermal refurbishments in the entire house stock are of importance to reduce the energy costs as much as possible. Indeed, the energy and water consumption costs are essential to determine these two rates

The results of these taxes variations are given in Table 4. A variation of +/- 0.5% gives a difference of +/-5% of NPV, but the payback time is almost identical.

Table 4. Analysis Results according to Rental vacancy and unpaid rent rates

Rate	NPV	ROI time
Rental Vacancy		
0.6%	105 %	41
1.1%	100 %	41
1.6%	95 %	42
Unpaid Rent		
0.4%	105 %	41
0.9%	100 %	41
1.4%	95 %	42

7. Discussion

One can notice the economic importance of the initial investment in this WLC. If initial investment was only considered as a matter of expense in the WLC, the social landlord will obtain almost 40% of the benefits from this operation. Contrariwise, if the whole-life costs are to be taken into account, this refurbishment operation project provides a benefit of about 13% of the rents in NPV.

The degree of uncertainty is higher for longer periods of analysis. Hence, the chosen period for economic assessment is not usually beyond 50 years. It could be observed that the discounted payback time is very important in this analysis, showing a beneficial situation or a non-beneficial one depending on the considered period of analysis. Considering 30-year-period, the building does not reach any payback on investment. On the contrary, for an 80-year-period, the payback time is equal to the one of 50-year-period. However, the NPV reaches 180%. The graph of cumulated NPV is presented in Fig. 3.

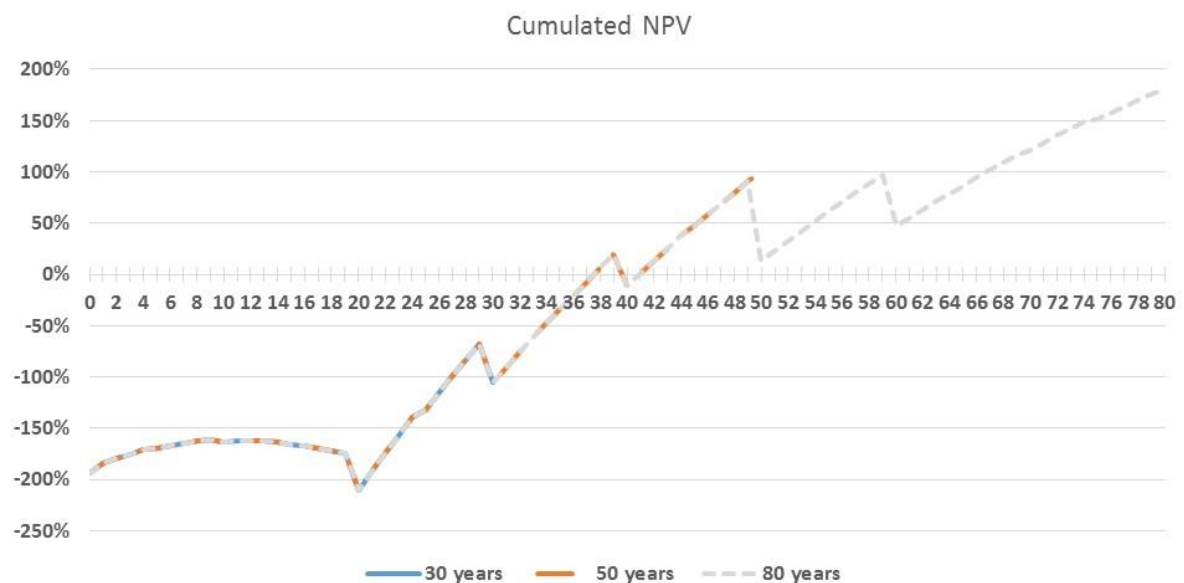


Figure 3: Cumulated NPV for 30, 50 and 80 years of period of analysis

The cumulated NPV presented in Fig. 3 is calculated as a percentage of 50 years cumulated NPV. Thus, for 50 years cumulated NPV it reaches 100% and for 30 and 80 years, the cumulated NPV is obtained according to the reference value.

Interestingly, it is more profitable for the social landlord to consider either a period of 50 years or a period much longer than 66 years. Indeed, the cumulated NPV after a period of 66 years equals the one reached after a period of 50 years. This is related to the planned replacements.

The sensitivity analysis highlights the importance of the rent discount rate. A decrease of 1% can result in +200% of NPV results. On the contrary, an increase of 1% can result in no return on investment

at all. Another important discount rate is the loan one. The fluctuation of this rate can result in a variation of + 75 % or - 75% of the NPV. The payback time varies accordingly. Hence those different rates must be chosen very knowingly.

8. Conclusion

This study discusses some methodological choices for building whole-life costing. It presents economic results of a typical refurbishment operation. It compares the results of WLC with the initial investment. Furthermore, it analyses the sensitivity of these economic results.

The corresponding results show the importance of considering the building whole-life costing instead of just the initial investment. While considering only the initial investment would give a very profitable operation, a whole-life costing presents lower returns on investment.

According to the sensitivity assessment, the dominating discount rate is the rent one. Its chosen value has the greater influence on the operation profit. The loan discount rate is important too. The results variation reached +/- 75%.

Attention must be paid to the choices of the different discount rates, as well as of loan period and lifetime period.

Next step of this project is investigating the case study eco-efficiency, based on those WLC results along with the corresponding LCA results.

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