Economic Feasibility Analysis of Sustainable Construction Measures

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ABSTRACT: The economical analysis of a construction project allows the feasibility evaluation on the monetary resources being applied, in terms of initial investment and / or future costs (operation, maintenance, etc.), considering equally technical liable options for construction.
This analysis gives the investor a more realistic and comprehensive approach about the investment he is about to make, and in what this results in terms of building use. The cost-benefit analysis can precisely demonstrate which economical benefits can be reached with what costs.
In this work the Life Cycle Cost – LCC - method (also called LCCA - Life Cycle Cost Analysis) was used to calculate the global cost associated to a construction project, though a specific period of time, comparing it to equivalent alternatives, so that the least global cost alternative could be defined.
The development of this method starts by making a life cycle study identifying every steps in which a project, service or product development is engaged, since its conception to the end of its life cycle, where that project becomes obsolete.
In a life cycle analysis, considering a sustainable point of view, environmental, social and economical aspects must be considered. In the specific LCC analysis only the economical aspects, associated with all evolved costs, are measured. Although the initial investment costs of a construction project can be very significant (construction stage) it's during the use stage that most costs are made, associated with normal use, maintenance, repairing, substation, etc., of the constructed space. This effect is also related to the duration of the use stage, compared to the construction stage. Also, the demolition, landfill and / or recycling costs must be considered as a part of all building costs.
In this work an analysis about the LCC, its objective, functionality, applicability and advantages was made. It was also a goal of this work to test this method applicability to a sustainable construction case study. In this example the LCC method was applied to determine the least global cost of a housing project considering a conventional vs. sustainable alternative project.

1 INTRODUCTION

This work aimed to develop an analysis about the LCC method and how it can be applied in the economical analysis of sustainable construction projects. In this application the LCC was applied to test which least global cost, in a housing project, can be obtained comparing a sustainable and a conventional project alternative.

The LCC is an economical evaluation method where all costs associated to the acquisition, operation, maintenance and final landfill are considered, being all important to investors decision.

Having these considerations in mind the LCC is particularly indicated to analyze different project alternatives, in terms of building conceptions that can match some desirable performance, as comfort needs, security, meeting legal requirements, etc., and that have different initial, maintenance, operation and reparation costs. The LCC can be easily used to evaluate different investments that have bigger initial costs but that can produce less costs through the life cycle, being an appropriate economical methodology to long term projects rather than the simple investment cost evaluation (Fuller et al, 1995).

This methodology gives the investor several data about the investment he is about to make, face to a group of technically liable equivalent options. Although, it’s important to refer that economical aspect can just be one of several selection criteria in construction projects, but, when considering equivalent technically liable options, this analysis can give the best choice considering the global cost of each alternative.

The LCC is a very demanding method that implies the evaluation of specific information on the investment and also on the present value cash flows, with the appropriated discount rate of the investment, according to the minimal rate of return presented by the investor.

A construction project’s planning, design and construction evolves several decisions, many of them purely economical. Nevertheless some decisions include other aspects: environmental, social, political, esthetic, etc. It´s important to refer that design has a crucial impact in the building future performance, in its operation and maintenance costs and, with that, its global costs. Because of that, LCC must be adopted since the project initial stages, supporting project choices that can be reflected in the use of the building. The detail in which this analysis can be made depends on the needs and goals of the owner, and can be developed to the complete building conception evaluation or in future material or construction techniques selection.

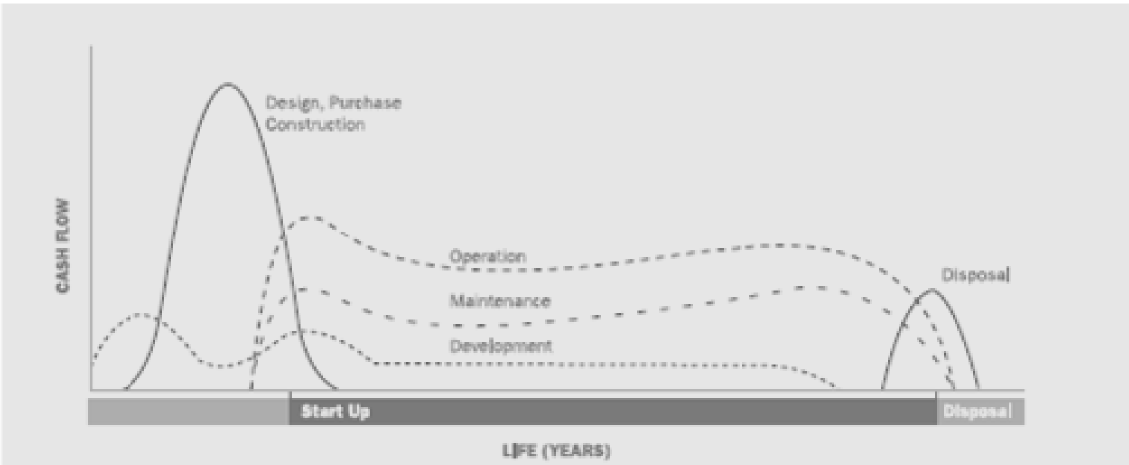

Figure 1 – Cash Flow related to construction projects (Australian National Audit Office, 2001)

It’s important to refer that the economical analysis developed by LCC can also be used in another different aspect. Knowing the global cost of several alternatives it’s also possible to establish an equivalent comparative base and define the choices to be done with other criteria (environmental, esthetics, etc.).

Any global cost study must be well documented in order to allow an objective evaluation of all steps of the decision making, when selecting the best alternatives, and also to make this information available to future evaluations.

2 LIFE CYCLE COST METODOLOGY

Independently the method to be chosen, the first step to an economical analysis corresponds to the description of the project and its general characteristics. In the specific case of construction projects, this information must focus on the building design as also on the type of occupation, activities and internal comfort needs. The alternatives criteria of evaluation and analysis must be developed according to this information, as also the technical and legal requisites to be considered.

After these, the acquisition, operation, maintenance and final scenario calculation processes must be developed according to all alternatives considered.

There are two cost categories that must be determined, namely:

- Investment Costs, generally associated to the initial moment of analysis in the LCC; and
- Operation Costs, to which all future costs are related.

The first ones are related to acquisition, installation, design, planning, etc. of the solutions being studied. The operation costs include all costs that result of the normal use of the solutions, its maintenance necessary to its corrected functioning, all reparation or substitution costs, and also costs associated to end of life that can be recycling of equipments or final landfill, etc.

Also the residual costs of the solution at the life cycle end must also be presented, if they exist, corresponding to the actual market value of the solution at the end of life cycle.

Both costs must be considered face to its annual value, so that the corresponding cash flow investment diagram can be developed.

After obtaining these costs and the cash flow diagram there's possible to calculate the Global cost of each alternative.

The Global Cost (CG) is given by:

$$CG = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t}$$

Where:

- Ct = Sum of all relevant costs occurring in the t period of time, including the initial investment costs (CF not actualized to year t)
- d = discount rate
- t = time period (period of the LCC analysis)

After the Global Cost methodology analysis it's possible to determine that there are several benefits in its use, particularly in construction projects.

Construction projects generally are projects that present significant investment costs, where it's crucial to develop the adequate economical to the investment to be made.

In practical terms the LCC allows the calculation of the costs that will exist in use stage of buildings, although the inevitable uncertainty when predicting future building consumptions and costs, and, with that, the global cost of several alternatives.

3 CASE STUDY APPLICATION

The project used as a case study corresponds to the Arcos de Santa Iria urbanization that is composed on 45 independent housing, located in the municipality of Óbidos, in Portugal.

All housing considered has three or four bedrooms, existing small variations in both typologies. The project was conceived in 2007 and the construction started in 2008.

Several sustainability measures were studied by the consultancy company ECOCHOICE S. A., according to the owner objectives on the project (ECOCHOICE, 2007). To this economical study only those that were chosen by the owner were considered.

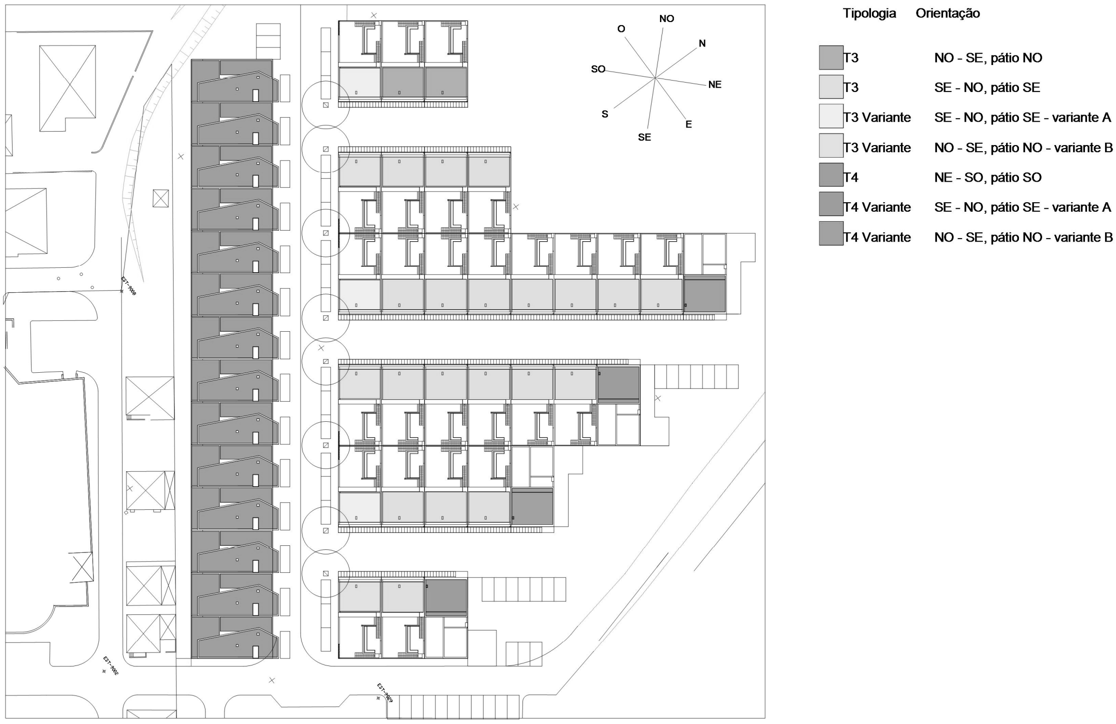

Figure 2 – Urbanization Arcos de Santa Iria – Óbidos, Portugal (ECOCHOICE, 2007)

Those measures were developed to improve the bioclimatic performance of buildings, the energy consumption and efficiency and also to reduce the water consumption. Other measures were also proposed but not included in the project.

To facilitate the LCC process the four bedroom typology was used as the element of analysis, so all costs were calculated according to its dimensions and characteristics.

According to the considered measures the conventional and sustainable scenarios were analyzed.

The main difficulties of the LCC method are related with the fact that some of the benefits and some of the operation and maintenance costs are very difficult to obtain and have large uncertainty. Some benefits are very difficult to translate into economical units, like indoor comfort, soil and biodiversity protection, etc.

To develop the economical analysis a thirty years period was consider, since this is the maximum period of time considered adequate to this method. Although buildings normally are planned to a minimum of fifty years of duration, a thirty years period of housing use can be considered as an acceptable average.

The discount rate used was about 7%, since this was the combination between the national Treasury bill rates with the risk rate of the investment.

To determine other costs calculations the energy tariffs (common to all municipalities) were analyzed and also the local water tariffs (that differ according to the municipality). The following values were found:

- Energy: 0,1143 €/kWh in low voltage electricity;
- Water: 0,74€/m^3 to consumptions between 11 and 30 m^3 for each two months.

In a general way, it’s possible to say that, in quantitative aspects, the sustainable measures are directly translated in monetary benefits though the reduction of energy and water, without interfering in the comfort perception by users.

All selected measures are divided into planning and integration areas, namely, in bioclimatic architecture to obtain passive ways to meet legal requirements; energy production systems and also water saving strategies.

3.1 *A Scenario –Conventional Construction*

The first investment option respects to the use of measures and equipments equal to common practice which doesn't represent any improvement to global performance, by comparison to traditional housing in Portugal.

These measures are:

- The thermal insulation will be composed by extruded polystyrene foam (XPS) with 4 cm;
- The slab will be directly constructed on the ground;
- The windows are simple and the frames have no thermal break;
- The electric devices and lamps have no energy efficiency label;
- The taps, showers and flushing tanks will be produced with standard materials and will have regular flows (10 and 15 liters per minute, respectively, and 10 liters per flushing);
- The domestic hot water (DHW) and the heating systems will be met though an electric thermo accumulator.

All these options were define in order to establish the most common construction strategies at that time. Its import to refer that, at the time the project was developed (2007) the energy performance directive, already translated to Portuguese laws, wasn't yet an obligation. Although, since 2008 this have turned to be an requirement to all news buildings, and, since then, the energy certificate to new buildings must be obtain in order to get the house use license.

This means the owner had to consider what measures he would apply to his its project in order to improve the energy performance in a time where these were not considered and where a lack of knowledge and expertise was still missing.

3.2 *B Scenario – Sustainable Construction*

To improve global sustainable performance of building, sustainable construction measures were analyzed and proposed, by changing the previously presented one's, in order to meet sustainable parameters. With these parameters the all house would be capacitated to improve its performance and, with that, to reduce resource consumptions and operation costs, though its life cycle.

The alternative measures considered to improve the bioclimatic performance of the house were:

- Cork insulation, locally produced, with 6 cm (larger than the XPS alternative considered);
- Ventilated Slab, by opposition to the slab-on-ground;
- Double glazing windows with thermal break frames, that have a extremely higher energy efficiency than those considered in the conventional construction;

These solutions will improve the passive performance of the building envelope reducing the energy needs to indoor acclimatization.

To minimize and optimize the remaining energy consumptions, there were proposed alternatives like:

- Electric devices and lamps with A-rated according to European energy label ratting;
- Also to reduce the energy consumption of equipments and electric systems a solar energy system to DHW, supported by the thermo accumulator, was proposed.

This strategies can reduce the direct use of electricity and also, though the solar system, develop local energy production systems, avoiding grid electricity use.

To reduce water consumption in taps and showers flux reduction devices will be considered and, to reduce flushing tanks water volume, double flushing tanks and, simultaneously, lower maximum volumes of discharge. By other hand, for pure environmental reasons, the chosen taps and showers are made of a special ecological material with no lead. This fact makes this investment more expensive than the normal materials that are used but doesn't reflect directly into economic benefits, when evaluating the global cost of the house.

This is one of the aspects that seriously difficult the LCC analysis when more intensive environmental measures and solutions are considered since there economic added value cannot be seen at local level (building, region, etc.) but at the positive impact to biodiversity or resource depletion, for example.

4 RESULTS

According to data presented in the previous chapters each alternative global cost analysis was developed, considering the initial investment costs but also the future costs that each alternative represents.

To do so, the unit average costs and also the initial costs were determined for each measure, to the four bedrooms house. To this house the project's information needed to make the global calculations, after the unit average costs have been determined, are:

- External walls area: 281,11m^2
- Roof area: 140,7 m^2
- Windows area: 24,98 m^2
- Slab area: 110, 49 m^2

Table 1 – A Scenario Investment

Solution	Type	Unit Cost	Units	Total quantity	Total Cost (€)
Insulation	XPS (4cm)	4,5	€/m2	313,81	1412,145
Slab	On ground	20,04	€/m2	110,5	2214,42
Windows	Simple	170,8	€/m3	25	4270
Lamps	Filament	1	€/lamp	24	24
Electric devices	E - rated	2500	€/kitchen	1	2500
DHW and heating	Thermo accumulator	300	€/equipment	1	300
Taps	Conventional	106,9	€/equipment	5	534,5
Showers	Conventional	456	€/equipment	2	912
Flushing tanks	Conventional	300	€/equipment	3	900
Total investment					13.067,065

For the considered solutions, has referred in table 1, the existing costs that are necessary to develop to LCC analysis, where calculated and presented in table 2.

To do this calculations some simplifications had to be made corresponding to users profile. In order to do so, a four element family was considered with a house occupation mainly during the late afternoon and night.

Some other simplifications had to be done, also considering the average consumption of water and electricity per occupant. Although this can bring some uncertainty to this study, this aspects is minimized by the use of the same simplifications in both scenarios.

Table 2 – Costs related to A Scenario – Conventional Construction

Conventional Construction		
Initial Investment	13067,065	€
Energy costs	1728,78	€/year
Water costs	117,22	€/year
Residual value (30 years)	0	€
Maintenance costs	0	€
Substitution costs (lamps)	48	€/year

In the B Scenario – sustainable construction, several changes occur when considering unit average costs, which can be seen in table 3.

Table 3 – B Scenario Investments

Solution	Type	Unit Cost	Units	Total quantity	Total Cost (€)
Insulation	Cork (6cm)	8,25	€/m2	313,81	2588,933
Slab	Ventilated	29,28	€/m2	110,5	3235,44
Windows	Double glazing (thermal beak frames)	248,89	€/m3	25	6222,25
Lamps	CFL	9	€/lamp	24	216
Electric devices	A rated	2500	€/kitchen	1	2500
DHW and heating	Solar energy panels and thermo accumulator	3470,45	€/equipment	1	3470,45
Taps	Ecological + flux reduction device	223	€/equipment	5	1115
Showers	Ecological + flux reduction device	990	€/equipment	2	1980
Flushing tanks	Double flushing (3 and 6 L)	300	€/equipment	3	900
Total investment					22.228,07

Has developed for A scenario, also to the sustainable construction options the life cycle costs were determined, through the same simplifications in terms of the users profile, has described before.

Table 4– Costs related to B Scenario – Sustainable Construction

	Sustainable Construction	
Initial Investment	22 228,07	€
Energy costs	387,93	€/year
Water costs	55,22	€/year
Residual value (30 years)	0	€
Maintenance costs	0	€
Substitution costs (lamps)	216	€/6 in 6 years

Has it can be seen, the initial investment of B Scenario – Sustainable Construction is about 1,7 times superior than the conventional option.

On the other hand the global cost of each alternative, which can be seen in next table, shows that, for the 30 years period of the study, the Global Cost of option A – Conventional Construction is about 1,5 times higher than the Sustainable Construction alternative.

Table 5 – Global Costs for both A and B Scenarios

Scenario	Initial Costs (€)	Global Costs (€)
Scenario A – Conventional Construction	13.067,06	45.454,36
Scenario B – Sustainable Construction	22.228,07	28.240,82

According to this analysis it's possible to see that the option in the implementation of the sustainable measures can be translated into an economy of 17.213,54€ in the thirty years scenario in which this study was made.

5 CONCLUSIONS

The Global Cost of the two alternatives made possible to conclude that the sustainable measures, in the 30 years period of the study, are liable, although they correspond to a larger initial investment cost. In economical terms, at the end of the 30 years, the sustainable measures, made possible an economy of around 17.000 €. This economy is due to the reduction of operation costs, that in the case are energy and water costs.

The main difficulties that this study revealed are related to the difficulty when trying to calculate in financial values the benefits that some of the measures can make. Also some difficulties were felt on predicting some maintenance and operation building costs. These were the reason why the residual cost for all measures and also the maintenance of the solutions, although that is not the most desirable way to make this approximation, were considered being null.

Other difficulties were found when trying to calculate the added value that these measures can bring to the building, by the improvement of indoor comfort and quality, user's satisfaction, etc. Also, there are other parallel effects that these solutions carry on, that are equally difficult to measure, like the reduction of green house gases, by the reduction of fossil fuels energy; effluents reduction, reducing the pressure in local treatment systems, etc.

Has an improvement to this analysis a study on how these parallel impacts can be translated in economical values would be very helpful and help to calculate the real effect of sustainable measures, through the building life cycle.

The sustainability measures considered in the case study represent only a few solutions that can be applied to sustainable construction. Other recommendation for future studies can be the development of projects with a larger complexity, considering, for example, other renewable energy systems, the use of gray and rain water systems, use of sustainable materials, solutions to improve soil and biodiversity protection, more complex bioclimatic solutions (green roofs, trombe wals, natural ventilations strategies, etc.) and also, some innovative solutions not yet developed.

By this study, it's possible to consider the LCC method very useful and objective when evaluating the economical liability of sustainable construction solutions that made possible to reach the initial goals for this study.

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