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The Modelling Building Life Cycle Costs with Software Support

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Abstract
In the focus of research activities there are building life cycle costs (BLLC). This research is interested in construction with a view to using new secondary raw materials and their impact not only on BLLC but also on all-society benefits. As the first step new software for BLLC calculation have created. The cost modelling is solved on the base of case studies. In addition to prices model works with lifetime of functional parts of building and their cycles of repairs and maintenances and time value of money (discount rate). The simulation with software support 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. BLCC of two or more alternative designs are computed and compared to determine which has the lowest LCC and is therefore more economical in the long run.

Keywords
Building life cycle costs, Economic efficiency, Secondary raw materials

1. Introduction

The basic condition for the feasibility of all projects is their economic evaluation. The aim of the research project dealing with the production and use of building materials made out of secondary raw materials is, apart from determining their production technology ensuring the required properties, also an economic evaluation of their application. The necessary condition for calculating the economic efficiency of using new building materials is the structuring of construction work to construction groups providing the required functions of the building. These construction groups are called functional parts (FP). Only some FP comprise building materials that can be made out of secondary raw materials. Therefore the costs for realization of FP are divided to substitutable materials, other materials, and other costs. Such structured costs form a database for subsequent modelling of other building life cycle costs. To calculate the building life cycle costs, software has been created which enables to calculate indicators when materials are substituted and conditions are predetermined by user.

2. Software for the Building Life Cycle Costs Calculation

Determining building life cycle costs is support for making decisions on investments put in the construction or reconstruction of a building. Life cycle costs include acquisition costs (investment costs) and operating costs connected with the technical parameters of the building, i.e. costs for maintenance, repairs and reconstructions of individual FP. For the indicator calculation, the evaluated period length can be set, the discount rate can be selected for calculations of the current cost values and of the expected life of individual FP.

The calculation is focused on substitution of selected materials and their impact on the overall building life cycle costs. It enables to compare individual material variants and to choose the optimum variant.

The life cycle costs calculation is performed using a method of calculation comparison with the selected building under predefined conditions. The database offers a set of case studies of buildings. The user works with input data shown in Table 1.

Table 1: Input Data

Calculation variant description	The user selects the calculation variant description individually.
Discount rate	The user selects the discount rate in %.
Evaluated period	The user sets the evaluated period length in years.
Existing project	The user selects a building for comparison calculation. The user selects a suitable building that shows the least deviations from the building of interest. It is the initial template on which the variant will be based.
Selection of functional parts	The user selects FP with which he wants to substitute materials. From the list, he sets their expected life spans for which the calculation will be made.
Materials for substitutions	From the list of materials for individual FP, the user selects materials that he wants to substitute. New values for the selected materials are entered in the form of total costs of the selected materials or new amounts of materials and unit prices.

2.1 Calculation of Variants

The variant calculation is performed based on the entered parameters and changes in the characteristics of the building at the level of alternative materials. The costs of functional parts for which material substitution is not made are considered on the percentage basis from the information on the building. The calculation of building life cycle costs (BLCC) is performed according to the following basic relation:

$$BLCC = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i} \quad (1)$$

Where;

BLCC = Building life cycle costs in monetary units
C_i = Investment or operating cost in i-th year of evaluation in monetary units
R = Discount rate in %/100
N = Evaluated period length in years

3. An Example of BLCC Calculation

The buildings in case studies represent templates which users can use in creating their variants. A building is comprised of individual FP defined in the application. For each entered FP there is a record which contains information on:

- substitutable material proportion,
- other material proportion,
- non-material components proportion,
- minimum life,
- maximum life,
- repairs cycle, and
- repairs extent.

Each FP with a non-zero proportion of substitutable material is supplemented with a list of substitutable materials showing its amount in FP. Each item of this list can be replaced with an alternative material.

3.1 Procedure for Creating Variants

Each variant is created using one of the existing case studies. As the first step the user selects a suitable building. By cloning the building definition to the variant structures a new variant building is created and the user can make the following changes in it:

- change the substitutable material in FP,
- change the FP life,
- change the FP repairs cycle,
- change the FP repairs extent.

3.2 Building Life Cycle Costs Calculation

For the calculation to be made the user must enter a discount rate and the monitored period length. For each FP, the application will display initial costs, continuous operating costs, and total costs for the evaluated period. These values are also expressed for the entire building. In the Table 2 below, there is a fragment of the BLCC calculation for a passive administrative building.

Selected variant: Passive administrative buildings
Discount rate: 3 %
Evaluated period: 25 years

Table 2: Fragment of the BLCC Calculation for a Passive Administrative Building (variant 01)

FP	Year (Discount factor)	0	6 (0.837)	11 (0.722)	16 (0.623)	21 (0.538)	Total [€]
Doors, windows	FP Inside doors (10/15)*	16 984,45	0.00	1 840,49	0.00	9 129,98	16 984,45 10 970,47 **27 954,92**
	FP Outside doors (10/15)	2 952,155	0.00	8 858.15	0.00	1 586,93	2 952,15 1 906,83 **4 858,98**
	FP Windows, balcony doors (20/15)	119 887,99	0.00	0.00	0.00	64 445,70	119 887,99 64 445,70 **184 333,69**
Floors	FP Thermal, sound, vibration insulations of floors and ceilings (10/15)	41 954,87	0.00	4 546,36	26 144,89	3 382,92	41 954,87 34 074,17 **76 029,048**
	FP Sub-floors (10/15)	36 618,82	0.00	3 968,13	22 819,64	2 952,66	36 618,82 29 740,43 **66 359,25**
	FP Paving (10/10)	992,93	0.00	71,73	618,76	53,37	992,93 743,87 **1 736,79**
	FP Sheet floors (5/100)	33 777,20	28 287,88	24 401,37	21 048,84	18 156,91	33 777,20 91 894,99 **125 672,19**
	FP Poured floors (5/100)	29 943,24	25 076,99	21 631,63	18 659,64	16 095,97	29 943,24 81 464,23 **111 407,48**
Service equipment		220 855,36	0.00	0.00	0.00	0.00	220 855,36 0.00 **220 855,36**
Other structures and work		104 743,84	0.00	0.00	0.00	0.00	104 743,84 0.00 **104 743,84**

** (10/15) means: FP has cycle of repair 10 years and range of repair 15 % from initial costs*

Model acquisition costs: € 1 916 981,00
Actual acquisition costs: € 1 916 793,20
Maintenance costs: € 399 930,00
Total costs: € 2 316 723,30

4. Theoretical Possibilities of Jointing the BLCC and LCA Methods

Generally, a Life Cycle Analysis (LCA) deals with environmental impacts of a product life from the acquisition of raw materials through production and use to their disposal. When applying LCA on building operations, the raw material demands, toxic effects of waste or intermediate products, etc. can be considered. The method does not deal with the economic and social impacts of a building, it is only focused on its environmental impacts. LCA is a comparative method in which various variants are mutually compared. The formation of each construction building is conditioned not only by material and energy inputs, but also during its operation and demolition a certain amount of energy and materials are consumed and the environment is loaded with emissions, waste and other adverse effects. The construction of buildings and their operation are primary consumers of materials and energies and significant polluters of the environment. During their entire life cycle, buildings in the EU consume approximately 40 % of energy, they produce about 30 % of CO_2 emissions and 40 % of all waste (RDA, 2003). It means that the adverse environmental impacts of construction and the operation of ground structures must be monitored and, if possible, reduced.

For the building life cycle cost calculation including the building life cycle impacts the relation (1) has been extended with all-society benefits – see (2).

$$C_{T,SB} = \sum_{i=0}^{n} \frac{\sum_{j=1}^{t} C_{Tj}}{(1+r)^{i}} - \sum_{i=0}^{n} \frac{\sum_{j=1}^{k} SB_{j}}{(1+r)^{i}} \qquad (2)$$

Where;

$C_{T,SB}$ = Costs connected with the technical parameters of the building including all-society benefits
C_{Tj} = *j*-th cost connected with the technical parameters of the building
SB_j = *j*-th all-society benefit associated with the technical parameters of the building in the evaluation year *i*
K = Total number of all-society benefits associated with the technical parameters of the building

The detailed methodical procedure for the evaluation of all-society benefits is under development. Particularly the method of sacrificed opportunity will be used for the monetary evaluation of benefits.

5. Conclusion

The BLCC indicator represents an important tool for decision-making in the variant utilization of building materials. In the period to come, the research team of the Institute of Economics and Management will deal with preparing the database upgrade of monetary evaluated all-society benefits which will be part of the building life cycle cost evaluation. The basic relations (1) and (2) for evaluation will be further developed. The comprehensive output of the research project can also serve as instructions for making decisions on supports for the research and development of new materials because it will be possible to prove, based on monetary evaluated inputs, the value of their all-society effectiveness.

6. References

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