Life Cycle Cost Optimization Within Decision Making on Alternative Designs

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ABSTRACT

This paper is to feature the importance of the life cycle cost criteria in decision making on the proposals of construction projects. Life cycle costing is a method for financial analyzing of all costs associated with initial construction, operations over its lifespan, and maintaining a construction project over a defined period. Obtaining the costs and savings, we can then directly compare these areas and be fully informed when decisions will be made. The most significant advantage of life cycle costing can be obtained in the initial phase of the construction projects. Construction cost and equipment cost is vital for a complicated decision-making process in the optimization of the life-cycle cost of a project. In this paper, a probabilistic life cycle analysis will be performed to compare precast concrete pavement over traditional onsite casting. With this solution, the minimal value of the life-cycle cost of pavement alternative can be selected. This paper will also discuss the issues of life cycle costing and difficulties analyzing it. The study will also help to clarify the necessary data, and a suitable process of life cycle costing will be proposed. Decision-making using the probabilistic life cycle cost optimization will be demonstrated in this paper using GAMS.

INTRODUCTION

The lowest cost is often the only absolute priority in the process of preparation of the budget in a construction project. If we consider a pavement lifespan as tens of years, assessing project alternatives with only investment costs occurs as shortsighted and insufficient. Running costs (operation costs, maintenance, and renovation costs) are an essential section of investment during the life cycle. Life cycle costing (LCC) should be an integral part of the decision making on financially high stake projects. Calculation of life cycle costs provides an entirely new economic view on pavement design. This study helps in understanding the implementation and incorporation of the LCC criterion in the decision making.

LCC is a technique to estimate the total cost of ownership (OGC, 2003). The technique can assist decision-making for investment projects (Flanagan et al., 1989). LCC is particularly useful for estimating the total cost in the early stage of a project (Bogenstatter, 2000). An LCC process usually includes the following steps: planning of the LCC analysis (e.g.definition of objectives), selection and development of the LCC model (e.g., cost breakdown structure, identifying data sources and contingencies), application of LCC model, and documentation and review of LCC results (NSW Treasury, 2004). Nevertheless, LCC is not usually adopted in The United States of America.

According to ISO/DIS 15686-5 (2006), Life Cycle Costing is both a tool and technique, which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital cost, future operational costs and asset replacement costs, through to end of its life. Also, LCC will take into consideration any other non-construction costs and income. LCC represents the overall costs spent in the course of the pavement's whole life cycle.

IMPLEMENTATION OF LCC IN DECISION MAKING

The LCC calculation should be used as a tool for effective selection of project alternatives in every phase of the project's life cycle, its effective use is in the design phase. Literature refers that 80 to 90 per cent of operation, maintenance are determined just by design. Implementing the LCC criteria in the decision making during the design will allow a more effective selection of competitive alternatives (design, detail, structure, equipment).

The value of the LCC criteria is set up based on LCC calculation. LCC may be a preliminary calculation or a detail calculation of LCC in the later investment phase (design phase). The detail LCC calculation is based on more specific project documents and data. For the decision-making process refer Table 2.

1	Defining the purpose and scope of decision
2	Defining of the range and key parameters
3	Summarizing data to the evaluated alternatives
4	Economic evaluation of alternatives
5	Selection of the optimum alternative

Table 2. Decision-making process based on LCC criteria

Total LCC are calculated in the frame of the economic evaluation. For example, either as the Net Present Value or the Annual Equivalent Cost.

CASE STUDY

The implementation of the concept for decision making in alternative design using LCC in this paper is applied in a small example which can be implemented to the enitre project with a similar approach. The example is basically carrying a LCC cost optimization of Precast Prestressed Concrete Pavement (PPCP) by finding out a way to reduce the cost of pavement over its life by initially investing more. For this model, hypothetical dimensions were considered. The calculations of the quantity were taken with respect to cost incured in one mile of pavement. The costs were taken as constraint and the total Life Cycle Cost was considered as objective to be optimized. By bound the objective function to be a higher value and the operational cost, maintenace cost and user cost to be lower values the code was run. The equation of NPV (objective function) is stated as below.

$$NPV = I + \sum M + O + U / (1+i)^n - S / (1+i)^n \qquad (1)$$

Where, C O = Initial construction cost; n= specific year of expenditure; i= discount rate; Mn= maintenance cost in year n; On= operating cost in year n; Un= user cost in year n; S= Salvage value (Scheving, A. G., 2011).

Case 1

In the first case we assume a considerable initial construction cost and low maintenance, operational and user costs.

Constraints	**Costs in US Dollar**
Initial Construction Cost	2,741,715.57
Maintenance Cost	189,746.995
Operational Cost	116,452.65
User Cost	1,037,382.55

By giving these equations as inputs the code was run and solution was found to be as follows: -

```
MODEL STATISTICS

BLOCKS OF EQUATIONS            7     SINGLE EQUATIONS              7
BLOCKS OF VARIABLES            7     SINGLE VARIABLES              7
NON ZERO ELEMENTS             13     NON LINEAR N-Z                6
DERIVATIVE POOL               20     CONSTANT POOL                16
CODE LENGTH                   20


GENERATION TIME      =        0.000 SECONDS      3 MB  25.0.3 r65947 WEX-WEI


EXECUTION TIME       =        0.000 SECONDS      3 MB  25.0.3 r65947 WEX-WEI
GAMS 25.0.3  r65947 Released Mar 21, 2018 WEX-WEI x86 64bit/MS Windows 05/02/18 23:56:12 Page 5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Solution Report     SOLVE LCCA Using NLP From line 27


               S O L V E      S U M M A R Y

     MODEL   LCCA                OBJECTIVE  z
     TYPE    NLP                 DIRECTION  MINIMIZE
     SOLVER  CONOPT              FROM LINE  27

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      2 Locally Optimal
**** OBJECTIVE VALUE          2741715.5700

 RESOURCE USAGE, LIMIT          0.000      1000.000
 ITERATION COUNT, LIMIT         4    2000000000
 EVALUATION ERRORS              0             0
CONOPT 3         25.0.3 r65947 Released Mar 21, 2018 WEI x86 64bit/MS Windows
```

RESULT

The net present value obtained for life cycle of 10 years is 2741715.57 which is nearly the same that we invested in the initial construction.

CASE 2

In the second case we reduce the construction cost by 40% which increases the costs over life span also by 40%.

Constraints	**Costs in US Dollar**
Initial Construction Cost	1,645,028.57
Maintenance Cost	265,645.8

Operational Cost	163,033.995
User Cost	1,452,335.55

```
               S O L V E      S U M M A R Y

     MODEL    LCCA                 OBJECTIVE  z
     TYPE     NLP                  DIRECTION  MINIMIZE
     SOLVER   CONOPT               FROM LINE  27

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE          2129900.3731

 RESOURCE USAGE, LIMIT          0.000      1000.000
 ITERATION COUNT, LIMIT         4     2000000000
 EVALUATION ERRORS              0             0
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                   Pre-triangular equations:   0
                   Post-triangular equations:  3


 ** Optimal solution. There are no superbasic variables.
```

RESULT

The net present value obtained for life cycle of 10 years is 2129900.37 which is lower than that obtained in CASE 1. That means the cost

CASE 3

In the third case we assume a significantly high initial construction cost.

```
               S O L V E      S U M M A R Y

     MODEL   LCCA                OBJECTIVE  z
     TYPE    NLP                 DIRECTION  MINIMIZE
     SOLVER  CONOPT              FROM LINE  27

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE          2910674.7417

 RESOURCE USAGE, LIMIT          0.000      1000.000
 ITERATION COUNT, LIMIT         4    2000000000
 EVALUATION ERRORS              0             0
CONOPT 3         25.0.3 r65947 Released Mar 21, 2018 WEI x86 64bit/MS Windows


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                   Pre-triangular equations:   0
                   Post-triangular equations:  3


 ** Optimal solution. There are no superbasic variables.
```

RESULT

When we run the code the value of objective function obtained is 2910674.7417. That means when the quality of construction is very high then the life cycle cost is reduced significantly.These three cases give us a clear picture to make decision in investing. Increasing initial construction cost certainly give us high net present value, but there is a certain feasibility limit to increase it. This model assumes hypothetical costs based on hypothetical data to show the optimization but in real world making a decision can be very hard and just picking up the high numbers (Initial construction cost) can not give the best solution.

SUMMARY AND CONCLUSION

It can be concluded with the below code that Precast concrete pavement is more economical than Cast-in-place concrete. Also, from the GAMS code it can be analyzed that higher initial construction cost will lower the maintenance cost and entire Life cycle cost of the project. As per the results obtained in GAMS code it can be concluded that the objective value is 2,741,715.57 for the analysis of fifth year after the construction of pavement which is an optimal solution. Hence this is a feasible approach.

GAMS CODE FOR LCC

```
Positive variable
I, N, n, M, O, U, S, i;
Variable
z;
equations
eq1
eq2
eq3
eq4
eq5
eq6
obj;
eq1..I=g=2741715.57;
*initial construction cost
eq2..M=l=189746.995;
*maintenance
eq3..O=l=116452.65;
*operational cost
```

```
eq4..U=g=1037382.55;
*User cost
eq5..i=g=0.04;
*discount rate range
eq6..n=e=5;
*year of analysis
obj..z=e=I+{[(M+O+U)/(1+i)**n]-[s/(1+i)**n]}
model LCCA /all/;
solve LCCA minimizing z using nlp;
```

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