EVALUATION OF ENERGY SAVING INVESTMENTS IN BUILDINGS AS A SYSTEM OF INTERDEPENDENT PROJECTS

Dalibor Vytlačil and Ondřej Povýšil
Czech Technical University in Prague
Faculty of Civil Engineering, Department of Engineering Informatics
Thákurova 7, 166 29 Prague 6, Czech Republic
vytlacil@fsv.cvut.cz

ABSTRACT
During a design stage building designers have to do many decisions that will influence an energy consumption in a designed building. Investments to a building structure and HVAC system are a basis for a low consumption of an energy. The decision making process is considered as the system of investment decisions where one certain decision is a project. The program has been developed for the selection of solutions for defined restrictions. One example is presented for the evaluation of different possible combinations of energy saving projects in a real building.

INTRODUCTION
Building designers and HVAC system designers meet different requirements of future or present owners of the buildings. Owners usually work with limited budget for the building construction but currently they are interested in low operating costs. This conflict can be solved by careful evaluation of investments to all arrangements that ensure low energy consumption. The building designers should find the best solution for stakeholders.

A decision process is described in Figure 1. In the beginning the future energy consumption is influenced by the decision about location of the building. It means latitude and also altitude. The site is exact position, e.g. a distance from other buildings. The choice of building structures and a kind of the heating system is the typical decision influencing energy consumption. Another action is the choice of a fuel because it creates the preposition for a good control of the heating source. The picture is based on general feasibility study approach (Behrens and Hawranek 1996).

The whole process can be broken down to more decision activities on the higher resolution level and also includes many back loops. The design is an iteration process when the building designers have to revise their decisions according to current situation.

Figure 1 Decisions influencing energy consumption and operating costs
A.

Initial operating costs

Project 2

Outcomes 2

Operating costs 2

Project 1

Outcomes 1

Operating costs 1

Investment costs 1

Figure 2 Basic generic structures - A) dependent projects, B) independent projects

B.

Initial operating costs

Project 1

Outcomes 1

Operating costs 1

Investment costs 1

Project 2

Outcomes 2

Operating costs 2

Investment costs 2

Figure 3 Influence of investment costs on outcome from dependent projects

METHOD

A decision making model is presented as the system of investment projects where same projects can influence financial outcomes from other projects. This fact is explained in Figure 2 where basic structures are presented. In the case A higher investments to Project 1 will ensure higher energy savings and it means better financial outcomes from this project but at the same time it decreases the cash flow from Project 2 (for the same level of investment costs in Project 2). The problem is described in Figure 3.

The conclusion is: to consider whole system of financial flows and projects as it is depicted in Figure 4. The structure creates the net where the node is the point of the decision and together with correspondent financial flows forms one single investment project. The network model is derived from the structure drawn in Figure 1.

The way of determining whether a project yields a return in excess of the alternative equal risk is to calculate the net present value (NPV). A positive NPV indicates that an investment should be accepted.

\[
E(NPV) = \sum_{t=1}^{m} \frac{CF_t}{(1 + i_t)^t}
\]  

(1)

Other technique for use in making investment decisions is internal rate of return (IRR). IRR represents the interest rate earned on the investment over the course of its economic life. It is the discount rate that will cause the net present value of the investment to be zero (Drury 1995).

\[
\sum_{t=1}^{m} \frac{CF_t}{(1 + i_t)^t} = 0
\]  

(2)

Evaluating the single project or the combination of the projects is based on the calculation of annual cash flows. In practice we have to consider many restrictions that influence the result. In this case, typical restriction is a budget. It means we have to work with the limited amount of financial sources that can be spent for all energy savings arrangements.

The computer program has been developed for assessing all combinations of selected single projects. The number of the combinations is defined by Equation 3.

\[
C_p = \sum_{k=1}^{n} \frac{n!}{k!(n-k)!}
\]  

(3)

In the first step, the user of the program chooses the single projects that will be considered for the evaluation and also the limit of investment costs. The program calculates all combinations of the projects and the user can decide that combinations will be evaluated and compared. In next step, needed data for the calculation of direct operating costs and financial outcomes are loaded.
EXAMPLE

General description

As an example, the evaluation of energy savings projects was performed for one flat in a 30 years old block of flats. Location: Czech Republic, Prague. Site: standalone block of flats. Flat is on the 3rd floor. Living area is 69 m². The heat source is a gas boiler. The boiler is located in the flat.

15 combinations of projects exist for four chosen single projects without the limit of the investment costs. For the limit 170 000 CZK, the number of the combinations is 14. The building user refused some combinations and therefore the final figure is 11.

Single projects

Project 1 - External thermal insulation of the building shell (80 mm thickness).

Project 2 – The replacement of old windows for new windows with better thermal parameters (Uframe = 1,13 W.m⁻².K⁻¹, Uglass = 1,4 W.m⁻².K⁻¹).

Project 3 – The installation of the window seal.

Project 4 – The replacement of old gas boiler for new boiler (η = 92%).

Combination of projects - independent projects

Project 5 – the combination of Project 1-Thermal insulation and Project 2-Windows replacement.

Project 6 – the combinations of Project 1-Thermal insulation and Project 3-Window seal.

Input parameters for calculations of NPV and IRR parameters for all projects are in Table 1. The project lifetime corresponds to the expected life period of the building structures and the elements of HVAC systems. The fuel price is very uncertain parameter. In this case, the price increase was estimated 5% every year. It depends often on political decisions and therefore the prediction for long period is difficult task.

<table>
<thead>
<tr>
<th>Project lifetime</th>
<th>[years]</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index of price increasing</td>
<td>[-]</td>
<td>1,05</td>
</tr>
<tr>
<td>Discount rate</td>
<td>[%]</td>
<td>8</td>
</tr>
</tbody>
</table>
Single projects

![Graph 1: Thermal insulation](image1)

- **Investment cost**: 65.2 \(10^3\) CZK
- **Savings 1. year**: 3.8 \(10^3\) CZK
- **Net present value (NPV)**: -6.7 \(10^3\) CZK
- **Internal rate of return (IRR)**: 7%

**Figure 5** Project 1: Thermal insulation

![Graph 2: Windows replacement](image2)

- **Investment cost**: 76.5 \(10^3\) CZK
- **Savings 1. year**: 2.3 \(10^3\) CZK
- **Net present value (NPV)**: -41.5 \(10^3\) CZK
- **Internal rate of return (IRR)**: -

**Figure 6** Project 2: Windows replacement

![Graph 3: Window seal](image3)

- **Investment cost**: 25 \(10^3\) CZK
- **Savings 1. year**: 1.4 \(10^3\) CZK
- **Net present value (NPV)**: -4.8 \(10^3\) CZK
- **Internal rate of return (IRR)**: 5%

**Figure 7** Project 3: Window seal

![Graph 4: Boiler replacement](image4)

- **Investment cost**: 141.7 \(10^3\) CZK
- **Savings 1. year**: 6.0 \(10^3\) CZK
- **Net present value (NPV)**: -45.7 \(10^3\) CZK
- **Internal rate of return (IRR)**: -3

**Figure 8** Project 4: Boiler replacement

![Graph 5: Thermal insul. + windows repl.](image5)

- **Investment cost**: 70.4 \(10^3\) CZK
- **Savings 1. year**: 4.4 \(10^3\) CZK
- **Net present value (NPV)**: -2.3 \(10^3\) CZK
- **Internal rate of return (IRR)**: 8%

**Figure 9** Project 5: Thermal insul. + windows repl.

![Graph 6: Thermal insul. + window seal](image6)

- **Investment cost**: 130.4 \(10^3\) CZK
- **Savings 1. year**: 4.4 \(10^3\) CZK
- **Net present value (NPV)**: -2.3 \(10^3\) CZK
- **Internal rate of return (IRR)**: 8%

**Figure 10** Project 6: Thermal insul. + window seal
Table 2
Rank of projects according to Net present value and Internal rate of return

<table>
<thead>
<tr>
<th>Project</th>
<th>NPV[10³ CZK]</th>
<th>Project</th>
<th>IRR [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-2.3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-4.8</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-6.7</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-15.3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-17.4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-41.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-45.4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>-45.7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>-57.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

Resultant values of main project parameters are in Figure 16. The rank of the projects is in Table 2.

The results written in Table 2 are the basis for the decision about the implementation of projects. The application of the IRR and NPV rules lead to the different order. The NPV ranking depends on the discount rate. In case of the discount rate lower than certain value (usually lower than 10-12%, but it depends on evaluated projects), the order of projects is different. The discount rates for energy savings projects are usually under 10%. The investigation of cash flow increments gives the priority to the NPV rule (Drury 1995).

It is not easy to compare independent and dependent projects in the real example because usually there are not sets of the projects with equal investment costs. In described case study, it is possible to compare e.g. Project 6 and Project 7 or Project 5 and Project 10. Independent projects reached better evaluation. The projects are mutually exclusive and therefore only one project (combination of single projects) can be accepted. The best ranked Project 3 has the lowest energy savings from all projects. The best energy saver Project 10 has the worst NPV. As a compromise, Project 6 was selected for the implementation. The project was realized three years ago. Financial outputs have been checked during this period with good agreement between calculated values and real values.

CONCLUSION

The paper was focused on the decision making process where building owner was the active element. It means, he was interested more in the profitability of the projects than in the maximum energy saved. Conclusions from the described problem:

- To define in the beginning the goals that should be reached by the implementation of the project. It means, to design these goals together with client (building owner).
- To prefer independent projects that ensure better investments effectiveness.
- The results can be changed by considering other financial outputs or non-financial benefits. E.g. increasing market price of the real estate or better functions of new windows.
- To consider the significant influence of the investment costs. It means, to spend enough time with the selection of the supplier. Decreasing initial costs can substantially change the results.
- The results are very sensitive to the price of fuel. This parameter influences strongly financial outputs from projects.

NOMENCLATURE

\[ CF \_t \] cash flow for certain year,
\[ m \] life time of projects,
\[ f \_i \] interest rate for certain year,
\[ i \] internal rate of return,
\[ n \] number of projects,
\[ k \] class of combination.

ACKNOWLEDGMENT

This research has been supported by MSMT grant No. 6840770006.

REFERENCES

Behrens, W., Hawranek, P.M. 1996. Manual for the Preparation of Feasibility Studies, UNIDO.